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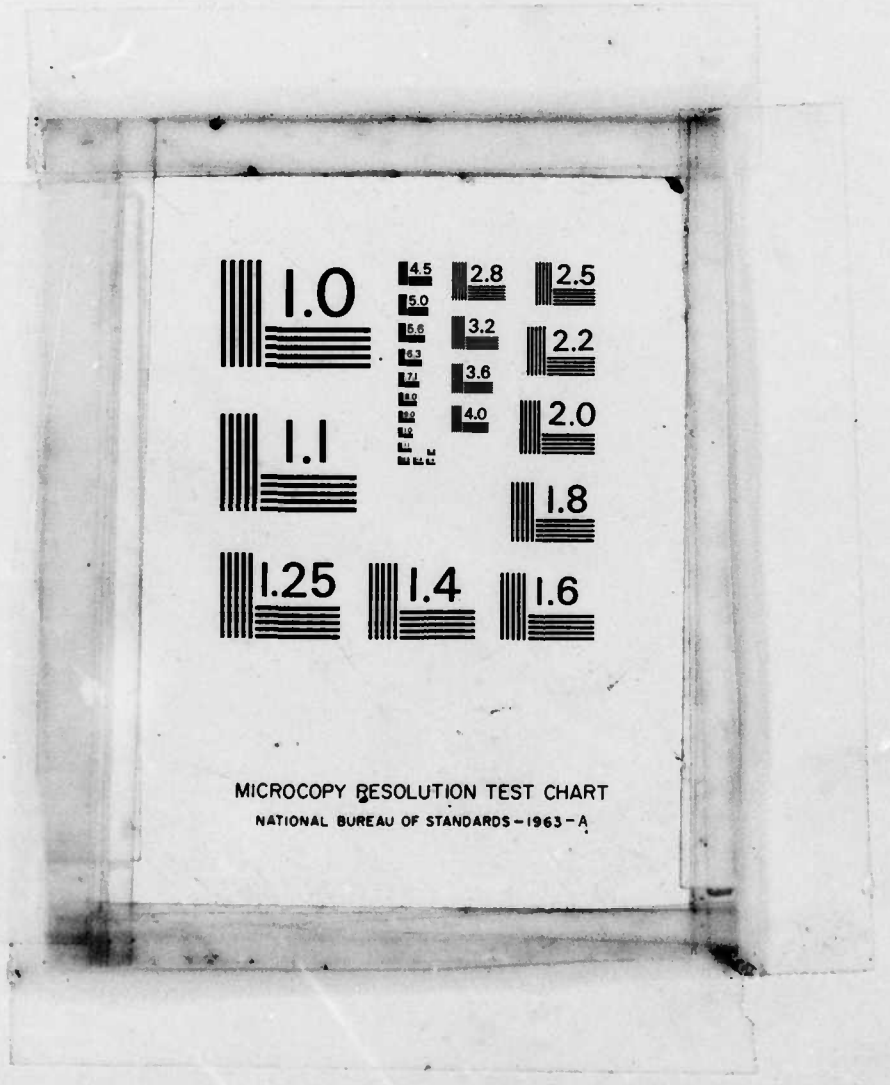
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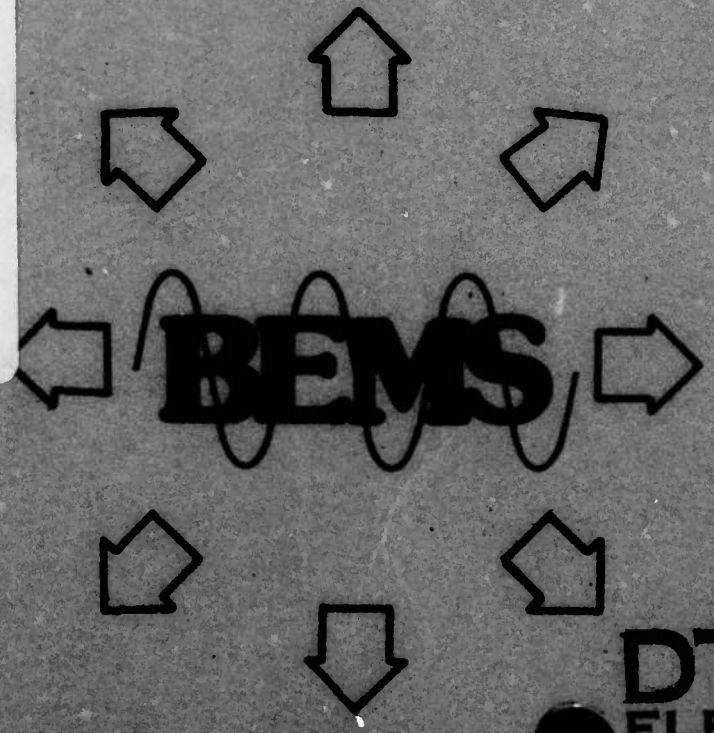

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ABSTRACTS

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THE BIOELECTROMAGNETICS SOCIETY

5th ANNUAL SCIENTIFIC SESSION

ABSTRACTS

Presented at
University of Colorado, Boulder
Boulder, Colorado
June 12-17, 1983

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SESSION A Cellular Effects I

Cochairs: Luigi Zecca and Robert P. Liburdy

A-1 EFFECTS OF TEMPERATURE AND MICROWAVE EXPOSURE ON THE ACTIVITY OF THE ATPase ENZYMES OF THE RED BLOOD CELL MEMBRANE. John W. Allis and Barbara L. Sinha*, Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711

We have exposed human red blood cell (RBC) membranes to 2.45 GHz CW microwave radiation and have measured the activity of the sodium-dependent and calcium-dependent ATPase activities of these membranes. Several reports have demonstrated an effect of microwave exposure on ion transport in whole RBC's in vitro. These results implicate the ATPase reaction. Two reports (Radiat. Res. 92:411, 1982; Ibid. 82:244, 1980) also showed a strong temperature dependent effect on ion transport, where the microwave effect occurred only at the transition temperature for each reaction studied. We have conducted a temperature series over the range 15-30°C to establish the temperature dependence for our system. The crossed-beam spectrophotometer system previously developed in this laboratory has been used to expose the RBC membrane samples and to measure the ATPase activities as a function of temperature. The SAR range is approximately 0.1 to 6 W/kg.

A-2 2450 MHz MICROWAVES AND CHEMICAL ONCOGENESIS IN VITRO. Elizabeth K. Balcer-Kubiczek*, George H. Harrison, and Duncan McCulloch*. Dept. of Radiation Oncology, Div. of Radiat. Res., University of Maryland School of Medicine, Baltimore, MD 21201.

In vivo acceleration of the development of benzo(a)pyrene (BP) induced tumors by 2450 MHz microwaves (MW) has been demonstrated. We report the results of in vitro experiments designed to determine whether long-term, low-level exposure to MW contributes to the cellular events during initiation phase of chemical oncogenesis. As an in vitro model, we used a C3H/10T½ cell system in which oncogenic transformation of cells can be scored after exposure to carcinogens. Our transformation assay and preparation of chemicals were similar to those previously described. In the experiments, cultures were treated in flasks completely filled with medium containing drugs (BP and/or DMSO). Cells were irradiated with MW in far-field TEM conditions with a mean specific absorption rate (SAR) of 3.8 W/kg in a temperature-controlled water bath located in an anechoic exposure chamber. A matching set of flasks was incubated at 37.5°C for the same treatment time of 24 hrs. Additional control groups included MW-irradiated and non-irradiated cultures without DMSO added to medium. Cytotoxicity of DMSO was 10%, and the plating efficiency was 20% in non-DMSO controls. An approximately 2-fold decrease in cell survival with a concomitant 10-fold increase in TR/colony in a 2.5 to 12.5-μM BP concentration range agrees with previously published results. However, the ultimate transformation yield and survival did not differ whether or not the MW field was present for the entire 24-hr initiation period. Under our test conditions using the C3H/10T½ system, MW had no effect on chemically-induced oncogenesis. This work was supported by the U.S. Office of Naval Research.

A-3 EXPOSURE TO A MODULATED MICROWAVE FIELD RESULTS IN A TRANSIENT DECREASE IN PROTEIN KINASE ACTIVITY IN HUMAN LYMPHOCYTES. Craig V. Byus, Robert L. Lundak, Ramona M. Fletcher and W. Ross Adey, Div. of Biomed. Sci., Univ. Calif., Riverside, CA 92521 and Research Service, Jerry L. Pettis Mem. VA Hosp., Loma Linda, CA 92537.

A possible mechanism by which hormone-receptor interactions at the cell surface lead to alterations in intracellular events is by the reversible phosphorylation of cellular proteins by protein kinases. For this reason we investigated the ability of brief exposure to low frequency electric fields to alter the protein kinase activity of human tonsil lymphocytes in culture. The cultures were exposed at 35°C in a Crawford cell to a 450 MHz, 1.5 mW/cm^2 (p.e.p.) field,, amplitude-modulated (depth 80%) at either 16 or 60 Hz for a period of up to 60 mins. Control cultures were placed in the same incubator alongside the Crawford cell. Protein kinase activity in cellular extracts was determined with mixed calf-thymus histone as the substrate under standard conditions. Extracts from control cultures (no field) had a total histone kinase activity of 52 $\pm$ 5 pmol $P^{32}/10^6$ cells, of which the activity due to specifically the cyclic AMP-dependent protein kinase was 10 $\pm$ 2 pmol $P^{32}/10^6$ cells. Exposure to the 16 or 60 Hz field for 15, 30 and 60 min did not alter the activity of cAMP-dependent protein kinase relative to the control cultures. However, the total non cyclic AMP-dependent protein kinase activity exhibited a transient decrease following 15 min (18 $\pm$ 3 pmol $P^{32}/10^6$ cells) and 30 min (19 $\pm$ 4 pmol $P^{32}/10^6$ cells) exposure to the 16 Hz field which returned to the control value after 60 min (45 $\pm$ 5 pmol $P^{32}/10^6$ cells) in the field. In the 60 Hz field a protein kinase was reduced to 80% and 75% of the control values at the 15 and 30 min time points only.

A-4 EFFECT OF INCREASED MAGNETIC FIELD ON AVIAN PINEAL AND RETINAL MELATONIN BIOSYNTHESIS. Gertrud Cremer-Bartels*, Kunibert Krause*, and Hans Joschim Küchle*. Eye Hospital of the Westphslian Wilhelms University, D-4400 Münster, FRG.

The hydroxyindole-O-methyltransferase (HIOMT) is the last enzyme of melatonin biosynthesis. We compared retinal and pineal HIOMT activity of groups of quails kept in incressed earth magnetic fields with controls after amplifying the horizontal component of the nstural magnetic field strength about 50 percent by Helmholtz coils. HIOMT is shown to respond to certain heterocyclic compounds. It may be suggested thst the phenomenons sre bssed on hyperfine couplings between electrons and nuclei which recently were found by Schulten to occur in low magnetic field strengths. We found significantly decreased HIOMT activity 60 snd 20 minutes respectively after exposure to increased magnetic field. However, effect on retinal HIOMT was found only 20 minutes after exposure.

A-5 MICROWAVE ABSORPTION CHARACTERISTICS OF HIGHLY PURIFIED E.coli DNA.

G. S. Edwards, Chemical Physics Program, University of Maryland, College Park, Maryland, 20742; M. L. Swicord, National Center for Devices and Radiological Health, 12709 Twinbrook Parkway, Rockville, Maryland 20857; C. C. Davis, Electrical Engineering Department, University of Maryland.

We have previously reported on the microwave absorption properties of E.coli DNA in aqueous solutions. Absorption was demonstrated in the 8 to 12 GHz frequency range using an optical heterodyne technique for detection. Similar studies were conducted using dielectrometric methods. We have extended the dielectrometric studies using highly purified E.coli DNA produced in our own laboratories and wish to report a significantly increased absorption by a DNA solution relative to the solvent. Furthermore, the protocol suggests a chain length dependence for the absorption; the absorption coefficient of a DNA molecule of a specific number of base pairs increases to about 400 times that of the solvent. Such an absorption partially supports the theoretical work of Kohli, Prohofsky, and Van Zandt.

A-6 EDDY CURRENT EFFECTS ON DNA SYNTHESIS AT GEOMAGNETIC INTENSITIES. Abraham R. Liboff and Louis D. Homer.* Naval Medical Research Institute, Bethesda, MD 20814

We have examined the relative uptake of 3H-thymidine in human embryonic foreskin fibroblasts in cell culture as a function of low frequency sinusoidal magnetic field intensity. A pair of incubators was used, fitted with matching 3-coil configurations to extend the field uniformity over a larger volume than could be obtained with a classical Helmholtz arrangement. Relative levels of radioactive thymidine uptake over controls were obtained in more than 100 trials. We infer that DNA synthesis in cells exposed to a varying magnetic field is significantly greater than the corresponding level measured in unexposed cells. This effect is observed over a wide frequency range, 10Hz to 4kHz, and between 0.2 and 4.0 peak gauss. Further, this enhancement reaches a maximum approximately 20 hours after the beginning of exposure, i.e. during the mid-S phase of the cell cycle. Among the cellular interactions that may be implicated in this effect is that resulting from Faraday's Law, $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$. Because of the discontinuity in conductivity associated with the cell membrane eddy currents so formed will exhibit both an extracellular and an intracellular component, the current density in either case scaling as the radius. We estimate the magnitude of this current density within the cell to be $\lesssim 10^{-5}$ μA/cm^2 for most of our experiments.

Supported by NMRDC work unit MR04101005.0004.

A-7 MICROWAVE EXPOSURE RESULTS IN THE SHEDDING OF PROTEIN FROM THE RABBIT ERYTHROCYTE. R.P. Liburdy, A. Penn. New York University Medical Center, 550 First Avenue, New York, NY 10016.

Previously, rabbit erythrocytes were shown to exhibit enhanced Na/K cotransport during microwave irradiation (2450 MHz, 10-100 W/kg) for exposures at membrane phase transition temperatures, 17-19°C (Liburdy, et al., BEMS Mtgs, LA, CA, 1982). Temperature-matched, water-bath treated control cells did not show this transport effect. Microwave and control cells appeared normal by light microscopy examination. We have investigated this phase transition phenomenon further and report that the release or shedding of protein from the erythrocyte occurs during microwave exposures conducted at 18°C. Following a 30-60 min irradiation or water-bath treatment, cell-free supernatants were electrophoresed on SDS-polycrylamide gels (12.5%) and protein bands were visualized by a sensitive Ag-Cl technique (ng resolution). Two low molecular weight proteins $\leq$ 30,000 D are released during microwave treatment, which are not present in the water-bath controls. In addition, microwave exposure results in the enhanced shedding of at least seven other proteins in this molecular weight range. These most likely represent "peripheral" or "extrinsic" cell-membrane associated proteins which are loosely bound to the cell surface via cationic bridges.

Supported by the Office of Naval Research, Contract #N0014-81-K-0669.

A-8 ELECTROMAGNETIC CURRENT INDUCTION MODULATES MEMBRANE BOUND ENZYME KINETICS: Na-K ATPase STUDIES USING A NEW FLOW SYSTEM. A.A. Pilla, K. Gary and C. Mayaud. Bioelectrochemistry Laboratory, Department of Orthopedic Surgery, Mount Sinai School of Medicine, New York, NY 10029

Induced pulsating currents, having waveform parameters designed to couple to cell surface electrochemical processes, have demonstrated considerable in vitro and in vivo effects. In order to quantitate the relationship between waveform parameters (pulse duration, amplitude, repetition rate) and biological effect, ouabain-sensitive Na efflux from human erythrocytes was evaluated. Freshly isolated cells were washed, placed in Na and K free Mg-sucrose solution and circulated (single pass) using a peristaltic pump through an annulus of defined radius between an air gap coil pair. Na^+ concentration was measured using an ion specific electrode. The single pass flow system allowed any change from Na^+ baseline, when exposed to induced current, to be observed. Results to date show that ouabain-sensitive Na^+ efflux can be increased by a maximum of 70% under the experimental conditions employed. This provides evidence supporting the hypothesis that electrochemical pathways involving ion binding may be the fundamental regulatory steps affected by electromagnetic fields.

A-9 THE KINETICS OF FIELD INDUCED CHANGES IN LOCAL BIOMOLECULAR CONCENTRATIONS. James R. Rabinowitz, Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711

The interaction of an external electric field with a biological system results in the movement of charged particles and the orientation of particles that have non-concentric distributions of positive and negative charge (in the field). It has been shown that this movement of charged particles can result in field induced local particle distributions that differ significantly from the unperturbed distributions and can affect biological function. This local particle distribution depends on local field strengths induced by the external field, the size of the compartment in which the particles are confined and the effective charge of the particle. The time required for a significant perturbation of the particle distribution to develop depends on the interaction of the particle with its surroundings, the temperature of the system and the size of the field. If the particles are intrinsic membrane proteins, it is likely to take many minutes before significant changes in local concentrations are induced by a 1 V/cm field because of the strong interaction of these particles with their membraneous environment and the cytoskeleton. This may vary by orders of magnitude for various membrane components. Smaller, extra-membraneous charge carriers will establish their perturbed distributions much more rapidly. The additional effects of orientation provide a mechanism for establishing perturbed distributions in more rapidly changing fields.

A-10 DEDIFFERENTIATION OF MAMMALIAN FIBROBLAST AND FIBROSARCOMA CELLS BY ELECTRICALLY GENERATED SILVER IONS. Robert O. Becker, Department of Orthopaedic Surgery, Upstate Medical Center, Syracuse, NY 13210

Silver ions emitted from pure silver anodes with voltages below 0.7V have been shown to have effective, broad spectrum, bacteriocidal and fungicidal properties, in vitro. The technique has also been found effective in clinical studies on wounds with severe, mixed infections. An unexpected finding, however, was a major acceleration in healing rate accompanied by the appearance of large numbers of primitive, blast-type cells in the wound. Since these are the cell type present in the regeneration blastema (and are not present in normal or electrically stimulated wounds in the human), their source was investigated. Using cultures of pure cell types this was traced to dedifferentiation of mature mammalian fibroblasts by the electrically generated silver ion. Chemically dissociated silver ions do not show the effect. Dedifferentiation of human fibrosarcoma cells in vitro, along with cessation of mitotic activity was produced by the same method. This technique may prove useful for producing the primitive cell populations necessary to promote rapid healing and possibly regenrative growth of human structures.

A-11 RF EXPOSURE OF MAMMALIAN CELLS. Stephen F. Cleary, Francine Garber*, and Li-Ming Liu. Department of Physiology and Biophysics, Virginia Commonwealth University, Richmond, Virginia 23298

Mammalian cells in suspension and in monolayer cultures were exposed to CW RF radiation in an investigation of electromagnetic field-induced functional alterations. Cells were exposed for 2-h in a temperature-controlled coaxial exposure chamber to 10-MHz fields at a SAR of 269 W/kg (4.8 V/cm), 50-MHz fields at a SAR of 170 W/kg (3.6 V/cm) or 100 MHz fields at a SAR of 154 W/kg (3.5 V/cm). A temperature-programmable circulating water bath controlled by the output of a Vitek probe placed in the RF exposed samples was used to duplicate the time-temperature history of the RF exposed samples in the sham-RF exposed samples. No field-induced alterations were detected in the viability or phagocytic activity of rabbit polymorphonuclear leukocytes exposed at 37°C. There was no statistically significant release of K^+ from rabbit erythrocytes (whole heparinized blood) exposed at 22.5°C but there was increased hemolysis in samples exposed at 50 and 100 MHz. The morphology and growth of rat glioma (C6) cells exposed as monolayer cultures at 37°C appeared to be affected by exposure to 100 MHz RF but there were no treatment effects on cell viability or LDH release.

A-12 X-BAND MICROWAVE EXPOSURE OF MAMMALIAN CELLS. Stephen F. Cleary, Francine Garber* and Li-Ming Liu. Department of Physiology and Biophysics, Virginia Commonwealth University, Richmond, Virginia 23298

The effects of microwave radiation on mammalian cells in culture and in suspension were investigated by exposing cells to 9.3 GHz CW microwaves for 2-h in a temperature-controlled cell incubator modified for far-field microwave exposure. A Vitek nonperturbing probe was used to monitor the temperature during exposure. The probe output controlled the temperature of a programmable circulating water bath, enabling simultaneous exposure of a sham-exposed control to the same time-temperature history as the microwave exposed samples. There were no detectable effects on the release of intracellular K^+ or hemoglobin from rabbit erythrocytes exposed in suspension as whole (heparinized) blood at SAR's of 12 to 14 mW/g and at steady-state temperatures of 32.2 or 39.6°C. Exposure of rat glioma (C6) monolayer cell cultures to the same SAR's but at a steady-state temperature of 41°C induced increased LDH release in immediate post-exposure samples and morphological and growth rate alterations in 48-h cultures, with no detectable effect on cell viability relative to heated-sham control cultures.

SESSION B Standards/Exposures

Cochairs: **Michael G. Shandala and Richard A. Tell**

B-1 ASSESSMENT OF LOW-LEVEL EMF BIOEFFECTS: IMPLICATIONS FOR SETTING NATIONAL RF/MICROWAVE EXPOSURE STANDARDS. Christopher H. Dodge* SPRD/CRS Library of Congress, Wash., D. C. 20540 and Zorach Glaser BRH/FDA, Rockville, Md. 20857, and P. Czerski.

Recent trends in public and scientific perceptions of biological phenomena associated with exposure to low-level electromagnetic fields are reviewed and analyzed. Such phenomena as calcium efflux in neural tissue; shifts in immune responses; and functional/behavioral changes are examined. Public perceptions, fears, and apprehensions about the possible health hazards of low-level electromagnetic fields are discussed and the origins of misperceptions are speculated upon. Federal regulatory and research programs and their status are assessed. Finally, a review of international RF/microwave exposure standards is presented and the present activity of state and voluntary standard-setting organizations is discussed.

B-2 SURVEY OF PROGRAMS TO ENFORCE MICROWAVE SAFETY STANDARDS. Robert C. Downs, Jr., Department of Physics, United States Air Force Academy, Colorado Springs, CO 80840.

In protecting individuals from the potentially harmful effects of microwaves, the enforcement of standards is equal in importance to the actual establishment of permissible exposure levels. Strict standards, unenforced, are little better than no standards at all. This issue was addressed briefly in questions during the 1982 Bioelectromagnetics Society meeting, but remained unresolved due to a lack of data on the subject. To remedy the situation, this paper reviews standards enforcement within the United States and, where reported, in other industrialized nations. These programs are not evaluated per se, but they are categorized in terms of the safety regimen established by Rexford-Welch and Lindsay in their paper on "The Practice of Microwave Radiation Safety," (J. Microwave Power, 11 (2), 1976). The criteria include safety officer appointments and the production of safety instructions, area control, the classification and medical surveillance of workers, and incident investigation.

B-3 QUESTIONS ON EMF HYGIENIC REGLAMENTATION IN POPULATED AREAS CONDITIONS. Yu.D.Dumansky. Kiev A.N.Marzeev Scientific Research Institute of General and Communal Hygiene, Popudrenko 80, Kiev-252160, USSR

Biologic effects of electromagnetic fields (EMF) of low frequency, high frequency, UHF and SHF range were studied. The results have shown that EMF produced by radiotechnical sources and electro-transmission lines appear to be biologically active environmental factor with the degree of effects depending on the frequency range, level and duration of action. The most sensitive to EMF impact is CNS. Definite changes were observed in cardio-vaskular system, metabolic processes, immune reactivity and generative function of experimental animals. High levels of EMF exposure are able to cause morphologic changes in brain, heart, liver, spleen and testicle tissues. The data obtained enabled to develop methodologic approaches to EMF reglamentation for populated areas together with the ways and measures of population protection and to outline the basic course of investigations in the area of EMF hygienic study of anthropogenic origin.

B-4 CHARACTERISTICS OF A HEALTH RISK ASSESSMENT AND APPLICATION TO 60-Hz ELECTROMAGNETIC FIELDS, Clay E. Easterly, Charles S. Dudney, Eugenia E. Calle, and P. J. Walsh*, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

A comparative framework is needed to understand the health risks of 60-Hz fields. The data base that supports a health risk assessment will include a description of the intensity and temporal sequence of exposure to toxic agents, and the body of information which includes data on levels of biological organization from subcellular and cellular levels to human epidemiological studies. A series of iterations between the biological research community and the assessment team is an important factor in improving the quality of the output. Ultimately, the credibility of such output depends on methodological considerations and especially on the data base undergoing analysis. At present, the data base for 60-Hz effects is growing, but the uncertainties associated with quantitative analysis are quite large. Not only is there a lack of consensus about what "dose" is, but exposure-response data at any level of biological organization is nearly non-existent. Consequently, considerable uncertainty will be associated with near-term estimates of risks for 60-Hz fields because of data gaps and lack of mechanistic knowledge. However, these uncertainties can be systematically characterized by employing assessment methods which integrate comprehensive human health oriented studies, and reduced by identifying research in critical areas.
*Operated by Union Carbide Corporation under contract W-7405-eng-26 with the U.S. Department of Energy.

B-5 EFFECT OF VLF FIELDS ON CARDIAC PACEMAKERS. Arthur W. Guy, Art M. Dong and Chung-Kwang Chou. Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

VLF electric field exposure levels that cause interference with implanted cardiac pacemakers were determined for a number of different exposure conditions including (1) in free space (2) body grounded through feet (3) body grounded through hand and (4) hand in contact with vehicles. The study was conducted for the purpose of quantifying possible hazards to persons using pacemakers who will commute on the new H-3 Interstate Highway in the vicinity of the Coast Guard OMEGA Navigation Station at Haiku, Hawaii. This station transmits 0.8 Hz pulse modulated 10.2-13.6 kHz signals. The performance of three models of bipolar and monopolar units, representing 87% of those used in the State of Hawaii, were monitored during injection of simulated OMEGA voltages. Exposure levels required to produce interference voltages at the implanted electrode terminals were calculated based on the VLF analysis diacussed in a companion paper. Results ahow that electric field thresholds for interference are well above 1 kV/m for exposure of an isolated subject but as low as 35 V/m when the subject is in contact with a vehicle.

B-6 HAZARD ANALYSIS: VERY LOW FREQUENCY THROUGH MEDIUM FREQUENCY RANGE. Arthur W. Guy, Chung-Kwang Chou and Art M. Dong*. Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

An analysis was performed to define the maximum VLF-MF electric field strength for human exposure to prevent biological hazards relating to shock, RF burns, and SAR exceeding the ANSI C95.1-1982 criteria (average 0.4 W/kg, maximum 8 W/kg). The analysis was based on (1) measurements of electric field strength, body to ground current and body to vehicle current under various exposure conditions near high power VLF transmitting antennas (2) body current distributions measured at 60 Hz by other authors and (3) measurements of body potential distribution resulting from impressed VLF current between head and feet. A computer model was devised to provide tables of average SAR, SAR distribution, current, current density, and absorbed energy in various parts of the body under a wide range of exposure conditions between 60 Hz and 3 MHz. Based on the results, maximum safe levels for human exposure to VLF-MF electric fields were found to be as low as 8 V/m for contact with large vehicles at exposure frequencies above 2 MHz and greater than 1 kV/m for free body exposures below 2 MHz.

B-7 BIOLOGICAL EFFECT OF CONSTANT ELECTRIC FIELD AND AIR IONS ON HUMAN BODY.
T.V.Kalyada, T.I.Krivova, V.N.Nickitina, M.V.Shepeleva. Leningrad Scientific Research Institute of Labour Hygiene and Occupational Diseases, Leningrad Institute of Labour Protection. Leningrad, USSR

The experimental study involved 10 volunteers. Responses of central nervous system (EEG, critical frequency of flicker blending), of central and peripheral circulation (tachooscillography, plethysmography, rheoencephalography), of thermoregulation system (thermography, heat radiation) on static electric fields of different intensities in combination with air ions was studied. Subjects were exposed daily for 2 hours a day during 20 days. The study was also carried out under simulated exposure and after the exposure. To give physical load of the given stereotype ergograph was used. Experimental results showed the dependence of the degree of manifestation and direction of human body responses on intensity of constant electric fields and on air ions current. The responses were found to be of compensatory-adaptive character. However, certain functional shifts were enhanced and cumulative biological effect was noticed after the exposure to electric fields of higher intensity.

B-8 THE SECOND DRAFT OF NEW CZECH STANDARD.Jan Musil,Institute of Hygiene & Epidemiology,Prague,Czechoslovakia

The contribution recapitulates the initial moments of introduction the CS standard in 1965 and its novelty in 1970.They are summed up the claims to arrangements for a nearest future : to introduce the ceiling limits for shorter expositions,to restrict the step changes, to arrange the limits on microwaves (including the consideration of an intermittent operation).On this basis the second draft of the new Czech Hygienic standard is presented together with a commentary.The author will discuss practical consequences of the proposed arrangements and also the sense and the way of the workplaces categorization.

B-9 HYGIENIC EVALUATION OF THE MICROWAVE RADIATION BIOLOGIC EFFECTS. M.I.Rudnev. Kiev A.N.Marzeev Scientific Research Institute of General and Communal Hygiene, Popudrenko 50, Kiev-252160, USSR

Considerable amount of experimental studies and reviews on microwave effects upon living organism are found both in soviet and foreign literature. The data presented are not always similar. In a number of cases they are contradictive and inadequate, demanding further activization and scientific development of the problem on microwave irradiation biologic effects. The basic point of this problem is scientific substantiation of hygienic standards, i.e. identification of this factor unfavourable (harmful) impact. Therefore lately attention of the soviet investigators was given mainly to the work of low intensity microwave effects: I to 1000 W/cm^2. Beginning from 1950 investigations on the problem of nonionizing radiation hygienic assessment are carried out in a number of countries, however even at present standards are set only for some ranges.

B-10 INTERACTION OF THE ORGANISM WITH ELECTROMAGNETIC FIELDS AS ENVIRONMENTAL FACTOR. A.M.Serdyuk. Kiev A.N.Marzeev Scientific Research Institute of General and Communal Hygiene, Popudrenko 50, Kiev-252160,USSR

At solving the problem of NIR bioeffects it is expedient to apply approaches of the experiment mathematic planning on the basis of "black box" cybernetic model. The factors biological activity is usually assessed by lots of indices. Therefore it is necessary to transform the results obtained into a generalized index, enabling to use one equation. Biological deviations obtained for each test (particular responses) are transformed into enormous scale d with following transfer to generalized index D according to the formula $D = \sqrt[n]{d_1 . d_2 \ldots . d_n}$, where n - quantity of the tests applied; d_1, d_2.... d_n - transformed particular responses for each test. Owing to such transformation with the organism deviations increase, particular indices d and generalized D are decreased. This fact may be (in a biological sense) logically connected with decrease of the organism stability if to take the control group stability for unity. That approach enabled to compare bioeffects caused by different NIR frequencies.

B-11 ADAPTATION TO NON-IONIZING RADIATION AS HYGIENIC PROBLEM. M.G.Shandala. Kiev A.N.Marzeev Scientific Research Institute of General and Communal Hygiene Popudrenko 50, Kiev-252160, USSR

The character of compensatory adaptative organism reactions and the degree of their manifestation under microwave radiation (MWR) were studied. Diagram of stepped adaptation with regard for recuperation period and functional loadings application was used at these questions settlement. Mathematic modelling of the organism compensatory-adaptative processes under MWR effects is carried out. The factor effects level at which exhaustion of the organism adaptative possibilities takes place we consider as the threshold of compensatory reaction and maximal values of the compensatory reaction - as the threshold of pathologic effects, that is such functional strain on its amount and/or duration to which the organism is not adapted evolutionally. Alowable values of the factor manifestation for the whole population are at the level of adaptative reactions limits, maximally allowable for the working persons - at the level ofcompensatory reactions limits and the maximally endurable - at the level of the limits of recuperative regenerative organism reactions under the factor effects.

B-12 REGRESSIVE ANALYSIS METHOD AT EVALUATION OF THE ORGANISM FUNCTIONAL STATE UNDER THE EFFECTS OF SHF ENERGY. *V.N.Soldatenkov, I.P.Los.* Kiev A.N.Marzeev Scientific Research Institute of General and Communal Hygiene, Popudrenko 50, Kiev-252160, USSR

At the example of pulsed-intermittent EM energy biological effects study, the experiment orthogonal central compositional planning was used enabling to obtain equation of the second order regression on each studied test. The results of the two experiments(the study was duplicated) made it possible to identify the most informative tests, accurate from the point of the result reproduction and enabling to obtain adequate settlement on the factor levels. The results of the investigations have shown that this regressive analysis method may be recommended for hygienic evaluation of environmental EM factors.

SESSION C Cellular Effects II

Cochairs: Inal G. Akoev and Sen Lin-Liu

C-1 PULSED AND CONTINUOUS WAVE 9.4 GHz HIGH INTENSITY MICROWAVE EXPOSURE EFFECTS ON CELL CULTURES. B.Bisceglia+, G.d'Ambrosio, P.P.Di Fiore+, A.Scaglione+, M.R.Scarfì+. -B.B., G.d'A., A.S., M.R.S.: Istituto di Elettrotecnica. -P.P.Di F.: Istituto di Patologia Generale (II). - Università di Napoli, Naples, Italy.

F4/6 Friend cells were exposed to 9.4 GHz pulsed (PW) and continuous wave (CW) microwaves and were conventionally heated. The exposure system was a multimode time-varying enclosure where the sample (1 ml serum-free suspension) was "isotropically" irradiated. During various sets of treatments the temperature grew from 30°C up to 45°C, 50°C and 55°C respectively. Exposures having the same time lenght and giving the same temperature rise were assumed as "thermally equivalent". Two hours after treatment live and dead cells were counted. The same was done on other reference cells, kept always in the incubator. The most interesting finding was that at the 50°C temperature level PW treatment gave dead cells percentages less than those obtained after CW exposure. Many repeated experiments under strictly controlled conditions gave the above experimental evidence of differential behaviour between PW and CW radiation, under high intensity exposure conditions. This was the first stage of our research: "chronic", low intensity experiments on the same cellular system are now in progress.

C-2 FURTHER INVESTIGATIONS ON RESONANT EFFECTS OF MM-WAVES ON YEAST. Luciano Furia, Om P. Gandhi, and Douglas W. Hill*. Departments of Electrical Engineering and Cellular, Viral and Molecular Biology, University of Utah, Salt Lake City, UT 84112.

Grundler, et al., have reported the presence of resonant effects in the growth rate of Saccaromyces cerevisiae cultures exposed to millimeter wave radiation around 41.780 GHz. Due to the importance of these effects in confirming the Fröhlich's theory of cooperative phenomena in biological systems, we have attempted to replicate them under rigorously controlled experimental conditions. Our system employs a klystron generator whose frequency is stable within ± 150 KHz as measured with a spectrum analyzer. The absolute and relative frequencies are measured with a resonant cavity frequency meter whose temperature is kept at 31.0 °C ± 0.05 °C. The relative shift of the irradiation frequency is known within ± 1.5 MHz. The irradiation chamber used has these features: simultaneous treatment of irradiated and sham exposed cultures, 99% power coupling, known power deposition pattern. The temperature difference between irradiated and control cultures is kept within ± 0.01 °C. The radiation used is a CW with a power in the waveguide of 20 mW, and an irradiation time of 4 h; the frequency step is 5 MHz. The cell counting method is the agar plate counting (i.e., a viability test). Results on the preliminary experiments will be presented.

C-3 RESPONSE OF CULTURED MAMMALIAN CELLS TO RADIOFREQUENCY RADIATION (RFR). Clifton R. Harris*+, Martin L. Meltz*+, and David N. Erwin. +Dept of Radiology, Univ. of Texas Health Science Center, San Antonio, TX 78284, and USAF School of Aerospace Medicine, Brooks AFB, TX 78235.

Chinese hamster ovary (CHO) fibroblasts were exposed to pulsed 850 MHz or 1.2 GHz radiofrequency radiation in the far field, at incident power levels which did not exceed 10 mW/cm^2. Normalized SAR values ranged from 0.15 to 0.66 at 850 MHz and from 0.12 to 0.39 at 1.2 GHz ($W/kg/mW/cm^2$). These power densities produced no detectable increase in temperature of the culture medium. Exposures were performed at 37 and 39 degrees C, the temperature being maintained by circulating water baths. No differences were observed in reproductive potential, growth kinetics, morphology, sister chromatid exchange and chromosome aberration frequencies among the control and exposed groups. It is concluded, therefore, that exposure of CHO cells to athermal RFR (850 MHz and 1.2 GHz) fields is not cytotoxic as judged by the parameters investigated. Similar studies at 9.3 GHz are in progress. (Supported by USAF Contract #F33615-80-C-0607).

C-4 EFFECT OF ELECTROMAGNETIC WAVES OF RADIOFREQUENCY RANGE ON THE STRUCTURE OF RED BLOOD CELL MEMBRANES. Yu. A. Kim*, B.S.Fomenko*, T.A.Agafonova* and I.G.Akoev. Institute of Biological Physics, Pushchino, Moscow region, 142292 USSR

The erythrocyte ghosts were labeled with 1-anilinonaphthalene-8-sulfonic acid, 1-toluidinonaphthalene-6-sulfonic acid, peryiene, pyrene and dimethyl-chalcone and exposed to 340 MHz microwave radiation (SAR 35 and 100 W/kg). Parameters of probe fluorescence were registered simultaneously with the irradiation. For one separate series of experiments we studied the labeling of phosphatidylethanolamine of whole erythrocytes with trinitrobenzene sulfonic acid during exposure to 900 MHz microwave radiation. The results showed that the fluidity of the hydrocarbon region of the membrane, the structural state of phospholipid polar head and the shielding of phospholipids by proteins were changed during electromagnetic wave-exposure. These changes were qualitatively similar to the heating effects.

C-5 THE EFFECTS OF PULSED MICROWAVES ON PRIMATE CORNEAL ENDOTHELIUM. Henry A. Kues*, The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20707, and Lawrence W. Hirst*, Salvatore A. D'Anna*, and Gregory R. Dunkelberger*, The Johns Hopkins University Wilmer Institute, Baltimore, MD 21205

Anesthetized cynomolgus monkeys were exposed to 2.45 GHz pulsed microwave radiation, and their corneas were examined utilizing specular microscopic photography. The average power levels for the 4 hour exposures varied from approximately 5 mW/cm^2 to 20 mW/cm^2 with pulse repetition rates between 50 to 100 pps and a fixed pulse width of 10 μs. Several non-exposed monkeys were also examined. The majority of primates that had been exposed to microwave power densities greater than 10 mW/cm^2 developed cellular abnormalities within a 24 to 72 hour period immediately following exposure. Histological examination of the affected corneas verified membrane damage and actual cellular dropout during this time. It was concluded that exposure to low level pulsed 2.45 GHz microwaves does produce cellular abnormalities in the primate endothelium under certain conditions.

C-6 INTERACTION OF ELECTRIC FIELDS AND IONIC CURRENTS IN AN EXCITABLE MEMBRANE: A NON LINEAR ANALYSIS. G.Morgavi and S.Ridalla. Istituto per i Circuiti Elettronici, C.N.R. - GENOVA - 16145 ITALY.

Interactions between biological structures and weak electromagnetic fields are suspected at the cell membrane. Non linear effects on ionic currents have been found. This suggest the use of the well known equations for the excitable membrane discovered by Hodgkin and Huxley. Two models have been considered. The first, using the linearization of the H.H. equations was used to confirm previous results with another membrane model[1]: strong frequency dependent behaviour of ionic fluxes was obtained. The second, using the complete non linear set of H.H. equations, was used to evaluate the average of the time dependent Na and K ionic currents. These terms represent the trasport phenomena involved when external electrical fields are applied to the membrane: they are considered the starting point of the biological modifications in the cell. The average flux is both frequency and amplitude dependent. These conclusions of course, cannot be extended to every experiment dealing with the interactions between electrical fields and biological structures, but they represents an interesting result which is based on a well accepted membrane model.

[1] Drago G.P. and Ridella S.; Br.J.Cancer 45 SUPPL.V, pag.215, 1982.

C-7 EFFECTS OF AMPLITUDE MOOULATED 147 MHz RADIATION ON THE MEMBRANE POTENTIAL OF CHARACEAN CELLS. William F. Pickard and Kathleen Montaigne*. Department of Electrical Engineering, Washington University, St. Louis, MO 63130.

A search was made for effects of low power, amplitude modulated very high frequency radiation on the membrane potential of Characean cells. The carrier frequency, modulation frequencies, and power levels used in this study were chosen to correlate with those found to be effective in stimulating calcium efflux in other excitable tissues. The membrane potential was measured at one end of a single cell of *Chara braunii* or *Nitella flexilis* while the other end was subjected to 147 MHz electromagnetic radiation at a nominal power density of 10 mW/cm^2, sinusoidally modulated at frequencies from 4-64 Hz. At 16 Hz modulation frequency the power was varied in steps from 0.2 mW/cm^2 to 100 mW/cm^2, concentrating on the range 0.2 mW/cm^2 to 5 mW/cm^2, since it is possible that any effect would be limited to a narrow power window. During the irradiation of the cell a lock-in amplifier was used to look for changes in the membrane potential occuring in synchrony with the modulation frequency. No such synchronized changes in the membrane potential were detected at the five nanovolt level under the conditions used in the study. The absence of an effect may reflect differences in calcium binding properties between Characean cells and the neural tissues used in the other studies, or it may be that a Characean cell requires a long period of irradiation to manifest any effects.

C-8 VACUOLAR HYPERPOLARIZING OFFSETS IN CHARACEAN CELLS EXPOSEO TO EM FIELDS IN THE BAND 0.2-1.0 GHz. William F. Pickard, Ashok V. Gokhale* and Kathleen M. Montaigne*. Department of Electrical Engineering, Washington University, St. Louis, MO 63130.

This investigation further characterizes the putatively thermal vacuolar hyperpolarization responses of Characean cells (Pickard and Barsoum, 1981) exposed to various intensities of squarewave modulated- and cw-electromagnetic fields over the band 0.2-1.0 GHz. The irradiation and micropipette-recording techniques employed were those of Pickard and Barsoum (1981). Vacuolar potential decreases slowly in a linear, ramp-like fashion for the entire duration of a radiation pulse (250 ms). Offsets were found to increase in magnitude with irradiation frequency over the entire band, in partial agreement with theoretical predictions. Electrogenic cells displayed significantly larger responses than non-electrogenic cells. Squarewave modulation at 1 kHz produced no significant alteration of response. In addition, offset magnitude was directly proportional to radiation power density at a given frequency, as would be expected for a purely thermal, power-dissipating response.

REF.: Pickard, W.F. and Barsoum, Y.H. (1981). Radio-frequency bioeffects at the membrane level: separation of thermal and athermal contributions in the Characeae. Journal of Membrane Biology 61, 39-54.

C-9 ELECTROMAGNETIC FIELD INDUCED GROWTH MODULATION of B. SUBTILIS BACTERIA, Ceon Ramon, Janice T. Martin, and Michael R. Powell, Institute of Applied Physiology and Medicine, 701 - 16th Avenue, Seattle, WA 98122.

For the past year, we have been examining the effect of sinusoidal and pulsed magnetic field induced growth modulation of B. Subtilis bacteria in the frequency range of 60Hz to 1000Hz and field strength of 0-30 Gauss. Based on our experimental results, we find that the growth curve of exposed bacteria as compared to the controls can be enhanced by 12% to 60% by increasing the field strength from 8 to 25 Gauss in the frequency range of 800 Hz to 1KHz. Several sets of data were taken by varying field strength and the frequency of the magnetic field. Theoretical analysis and the experimental results show that the best modulation of the growth curve was obtained when bacteria were exposed to a 1KHz field modulated by a slowly varying field at 0.25Hz. The experimental setup consists of a pair of resonant Helmholtz field coils attached to a water bath kept at a constant temperature of 32.9°C. Exposure samples were kept between the field coils and the control samples enclosed inside the magnetic shielding material kept at the same temperature away from the field coils. Magnetically shielded controls were divided into two sets. One set was exp sed to the acoustic tone noise generated by the field coils and the other set totally shielded from the noise. In this way we were able to separate acoustic and magnetic field effects.

C-10 EFFECT OF 330 MHz RADIOFREQUENCY RADIATION ON THE HUMAN ERYTHROCYTE GHOSTS. Valery L. Shnyrov*, Galina G. Zhadan*, Inal G. Akoev. Institute of Biological Physics, USSR Academy of Sciences, Pushchino, Moscow Region, 142292 USSR

Irreversible changes of heat capacity of human erythrocyte ghost suspension due to the effect of 330 MHz radiofrequency radiation (SAR vas found near 10 W/kg/ were detected by the method of scanning differential microcalorimetry and infrared spectroscopy. Condencer type of irradiation was used: germetical silica chamber filled with membrane suspension was placed between two cooper plates connected to radiofrequency generator. The results of heat capacity measurements showed that the initial level of the specific heat depends on the irradiation time, and the total heat effect of thermal convertion significantly decreases. The temperature of maximum for transition corresponding to the heat absorption of transmembrane domain of band 3 protein is displaced to the side of the most low meaning. All these changes reach the definite stationary level already at 15 min of irradiation. The character changes observed in infrared spectra points to the decrease of hydrogen-bond formation, apparently affecting the band 3 protein.

C-11 EFFECT OF A PULSATING MAGNETIC FIELD ON EHRLICH ASCITES TUMOR CELLS.
Luigi Zecca and Girolamo Dal Conte. Istituto di Farmacologia and Clinica Ortopedica IV. Facoltà di Medicina e Chirurgia, 20100 Milano. Italy.

The effects of a pulsating magnetic field (50 G, 50 Hz) generated by a therapeutic device (Ronafor) on Ehrlich ascites tumor cells, in vivo and in vitro were evaluated. The interference on tumor growth in vivo and respiration in vitro were measured. Cells ($4x10^7$) obtained from ascitic fluid were exposed to the field for 30 minutes. Viability assayed by Trypan Blue dye test was unchanged. Respirometric proofs were performed with cells subjected to the previously described exposure and the oxygen consumption (41.5 $\pm$ 2.1 μl O_2/hour) did not change significantly. In vivo experiments were carried out with seven groups (A-G) of 20 female Swiss mice injected i.p. with tumor cells. A was the control group; B,C and E were exposed to the field 3 hours daily, respectively for 1-5 and 7 days after injection. F group wasinjected with cells, just before exposed 30 minutes to the field. G group was treated 7 days before plus 7 days after injection. The days of survival after injection were recorded. Only in G group was found a significant increase of survival (10.9%, $p<.004$) versus control. All other groups did not show variations in mortality. These results evidence that in these conditions the growth and respiration of tumor cells are not directly affected. The observed decrease of mortality, could be due to an immunostimulation effect.

C-12 Low-Level Milimeter Irradiation and Colicin Induction.
S.M. Motzkin, L. Benes*, L. Birenbaum, S.W. Rosenthal, and Q. Han*. Polytechnic Institute of New York, Brooklyn, NY 11201.

Smolenskaya & Villenskaya's reports of enchanced colicin production in E.Coli et specific wavelengths between 6.50 and 6.59mm which eppeers to be insensitive to power density over two orders of magnitude and suggests a resonance phenomenon are being reexemined. W 3110 ColE$_1$ cells in lag, log, or stetionery phase ere irradiated in a water-jacktetd temperature controlled cell with continuous waves at 0.01mm intervals between 6.50 and 6.59mm for sixty minutes et 37° centigrade and at power densities of 5, 0.5 and 0.05mW/cm^2. Exposures cerried out with standerd waveguide systems terminating in a horn permit the determinetion of reflections, frequency, and power density. Colicin induction is determined by a soft ager overley technique which permits exeminetion of colicin induction by single cells es clear arees. Results obtained to date at these wevelengths do not show stetisticel evidence of colicin inducibility.

SESSION D Medical Applications

Cochairs: Charles A. Cain and Richard H. C. Bentall

D-1 AN ULTRASOUND HEATING SYSTEM USING SCANNED FOCUSED TRANSDUCERS. Robert J. Dickinson*, Jeffrey W. Hand* and John L. Ledda*, MRC Cyclotron Unit, Hammersmith Hospital, London W12 OHS, U.K.

Ultrasound heating (0.3 - 3 MHz) offers better localization and penetration than most electromagnetic forms of heating and its use for local heating in clinical hyperthermia appears attractive. Temperature distributions produced by three different ultrasound systems were calculated using a computer model of heat transfer in tissues. A single plane (unfocused) 1 MHz transducer can heat down to 3 cm but it is difficult to constrain the heating to the target volume alone. A 1 MHz focused transducer gives good penetration and preferential heating at depths of up to 8 cm but the long and narrow shape of the heated volume is unsuitable for most clinical applications. A focused transducer scanned repetitively across the skin surface gives a larger heated volume whose shape can be determined by the area of the scan. Scanning reduces the preferential heating at depth. A prototype ultrasound heating system in which an electronically switched array of 6 focused 1 MHz transducers is mechanically scanned was constructed. Temperature distributions produced in tissue equivalent phantoms were compared with theoretical predictions. These results suggest that a scanned array of ultrasound transducers should prove useful in clinical hyperthermia.

D-2 EM PROBING AND HEATING WITH A MICROCOAXIAL PROBE. Abdolhamid Ghods and K.M. Chen, Department of Electrical Engineering and Systems Science, Michigan State University, East Lansing, MI 48824

A microcoaxial probe consisting of a very thin coaxial line with a protruding center conductor can be used to measure the local conductivity and permittivity, or to locally heat a region inside a biological body. The conductivity and permittivity of the body are measured indirectly by measuring the input impedance of the probe. Local heating of the body is accomplished by the near-zone field of the probe which is maintained by the induced current on the center and outer conductors of the coaxial line. We consider the geometry of a thin coaxial line having a protruding center conductor at the open end and an outer conductor coated with a surface impedance (to attenuate the induced current) and not connecting to a ground plane. The probe either bare or covered by an insulating layer is embedded in a conducting medium. The bare probe is analyzed on the basis of an integral equation for the induced current on the probe and the coaxial line with a magnetic frill source. The insulated probe is analyzed with a generalized transmission theory. It was found that both bare and insulated probe can be used for local heating, but the insulated probe is not useful for the measurement of conductivity and permittivity due to its unattenuated induced current on the surface of the coaxial line. Experiments were conducted to verify the theory.

D-3 915 MHz PHAZED-ARRAY SYSTEM FOR TREATING TUMORS OF HUMAN LIMBS. Arthur W. Guy, Chung-Kwang Chou, Kenneth H. Luk* and Carrol Sorensen. Bioelectromagnetics Research Laboratory, Departments of Rehabilitation Medicine and Radiation Oncology, University of Washington, Seattle, WA 98195

A phased array system using eight 915 MHz square cavity applicators (13 x 13 cm) previously developed in our laboratory was designed to heat both deep and superficial tumors of the leg. Pairs of applicators were assembled so that they could be placed every 90° around the periphery of the limb, completely surrounding it with an 8 element array. The relative phase and amplitude of each applicator can be controlled to provide the best therapeutic heating pattern for a particular location or region. A theoretical and experimental study was made of the range of SAR patterns that could be produced in the limb using the array. The system was tested for its effectiveness in treatment of a patient with melanoma of the lower leg. During treatment 8 channel Vitek 101 temperature probes were used for monitoring and controlling the tumor temperature at 43° C.

D-4 LOW PROFILE APPLICATORS FOR ELECTROMAGNETICALLY INDUCED LOCAL HYPERTHERMIA Jeffrey W. Hand*(1), Reginald H. Johnson*(2) and James R. James*(2), (1)MRC Cyclotron Unit, Hammersmith Hospital, London W12 OHS (2) Dept. Electrical and Electronic Engineering, Royal Military College of Science, Shrivenham, England.

A range of low profile applicators operating at frequencies between 1 GHz and 100 MHz has been developed for use in local hyperthermia. Each applicator is based on a resonant element radiator which is enclosed in a low loss material backed by a metallic ground plane. By suitable choice of this material (high ϵ' and allowing $\mu_r > 1$) the size of the applicators may be reduced whilst a good impedance match to the tissue is maintained. Applicators operating at 915, 433 and 200 MHz are discussed. Tests involving simulated tissues show that a nearly uniform heating pattern corresponding with the shape of the radiating element can be obtained. Measurements of specific-absorption rate, penetration depths and leakage field associated with these applicators compare favourably with the most successful of existing waveguide and microstrip loop applicators. The characteristics of the applicators when used to heat the thighs of anaesthetized pigs were also determined+ and were similar to those found when heating phantoms. Patients with superficial lesions in various anatomical sites(eg chest wall, axilla, neck) have been heated with low profile applicators. As the laboratory tests for performance indicated, the applicators were effective and simple to use under clinical conditions and provided good power transfer with low leakage.

+ In collaboration with J.W. Hopewell, Churchill Hospital, Oxford, UK.

D-5 GRADED LESIONS PRODUCED WITH MICROWAVES AT 915 MHz IN THE RABBIT SPINAL CORD. Carl H. Sutton, Pava Popovic*, and Craig McKnight.* University of South Florida and Veterans Hosp., Tampa, FL 33612, and Emory University, Atlanta, GA 30345.

During studies to delineate the upper limits of tolerance of rabbit spinal cord to focal hyperthermia, lesions were produced which resulted in varying degrees of weakness or paralysis in the hind limbs. Large (ten-pound) male New Zealand white rabbits are suitable experimental animals in which intraspinal thermometry can be maintained during microwave heating at 915 MHz. A spinal cord injury model has been developed, using precise dosage levels of segmental hyperthermia in the thoracic spinal cord, so that lesions of predictable severity with reproducible degrees of neurological deficit can be produced as desired. In addition to grading the spinal cord lesions with respect to residual neurological function, dose-response observations, utilizing somatosensory evoked responses, blood-spinal cord barrier tracers, and neurohistological and enzyme-histochemical preparations, indicate that it will be possible to use this approach to develop a standardized, calibrated model in rabbits. Dose-response observations demonstrate that lesion size and severity are directly proportionally to the dose of hyperthermia administered. Evaluation of the efficacy of new therapeutic modalities for the treatment of spinal cord injury will be facilitated by the development of a new, non-invasive model for graded injuries in rabbits. (Supported in part by grants from the VA, Amer Cancer Soc, Fla Div.)

D-6 EFFECT OF 27.12 MHZ PULSED FIELD ON HUMAN DERMAL STRIPPED WOUNDS. Richard H.C. Bentall, Diana Beard* and Gillian Gillis*. Institute of Biolelectrical Research, Romanno Bridge, West Linton, Peeblesshire, Scotland.

To ascertain whether there was an alteration at the rate at which a dermal skin injury would recover, we used water loss as a means of estimating dermal damage and rate of repair. On a group of 10 human volunteers, a dermal stripped injury of at least 10 cms in length and 2 cms in width was inflicted on each forearm. Water loss was measured immediately using a Servomed evaporimeter which determines relative humidity. Double-blind pulsed radiofrequency devices were then applied over each forearm wound; one device was active and the other a placebo. The devices were held in position for at least 16 hours per day, and daily evaporimeter measurements were made. The alteration in water loss from the site of the injury were measured simultaneously with that of the control area. This was achieved by using 2 probes and alternating the position of each for a series of 3 measurements, made once a day. An average reading was taken from these measurements of the injured site. At 3 days, there was an alteration in the initial repair rate of one-half the water loss from the dermal injury site on which the active coil was used. This result concurs with other recent research, using 100 μ/sec pulses with a repetition rate of 1 KHz having an out-put less than 10 μ/W from the treatment coil, demonstrating potential therapeutic uses for skin wounds.

D-7 CLINICAL EXPERIENCE WITH LOCAL MICROWAVE HYPERTHERMIA AND RADIATION. John C. Blasko, M.D.† Douglas R. Schumacher, B.S.‡ and Tilmer O. Engebretson, Jr., M.A.*
Swedish Hospital Tumor Institute, Seattle, WA 98104.

Thirty-nine patients with superficial or subcutaneous malignancies were treated with various combinations of local hyperthermia and radiation. Hyperthermia was delivered with a BSD-1000 microwave hyperthermia system. Issues of heating adequacy, temperature monitoring, patient tolerance and preliminary results will be presented.

D-8 THE HEALING OF BONE DELAYED UNIONS BY ULTRASOUND STIMULATION.
Luiz R. Duarte, Bioengineering Programme - University of Sao Paulo, Brazil

The application of low ultrasonic energy with appropriate parameters has been investigated in clinical trials after years of animal experiments. The patients have been selected among desperate cases of pseudarthrosis that have been treated before by conventional orthopaedic technique with no success. Up to now 160 cases have been stimulated by ultrasound with an overall healing rate of 76%. The treatment consists of 30 to 60 daily stimulations through the skin and can be applied for any kind of bone (cortical or cancellus bone). The mechanism of the method seems to be mostly founded in the bone piezoelectricity and a model has been proposed in this way. Ultrasonic parameters like: pulse width, repetition frequency, radio frequency, intensity and exposure time have been optimized through a multicenter collaboration project.

D-9 ELECTROCHEMICAL AUGMENTATION OF ANTI CANCER CHEMOIMMUNOTHERAPY WITH PULSATING ELECTROMAGNETICALLY INDUCED CURRENTS (PEMIC). L. Norton, A.A. Pilla*, S. Geller and L. Tansman. Department of Neoplastic Diseases and *Bioelectrochemistry Laboratory, Department of Orthopedic Surgery, Mount Sinai School of Medicine, New York, NY 10029

This study presents new results and approaches to previously described experiments on a new electrochemotherapeutic method designed to have anti-tumor activity in vivo. Both cytotoxic and immune modulation chemotherapy were associated with PEMIC to treat BDF_1 or BCF_1 mice having B16 melanoma, Ridgeway osteogenic sarcoma and spontaneous C3H mammary adenocarcinoma. The effects were assessed by observation of survival time, rate of tumor growth and histological examination. For all tumors tested, survival times were significantly longer when PEMIC plus chemotherapy was employed vs. those with PEMIC or chemotherapy alone. For example, at a median survival of 7 weeks, 24 mice with PEMIC alone were not different from 28 mice treated with PYRAN (an immunomodulating agent) or with untreated controls. However, 20 mice having PEMIC + PYRAN had a median survival in excess of 10 weeks. Histologic examination has revealed central necrosis of individual nodules or marked cellular volume expansion. These results are related to real-time electrical dosage, considering the tumor mass to be electrically isolated from surrounding tissue (shown by impedance measurements, and to the model dependent energy spectrum of the induced current waveform.

D-10 ADJUVANT USE OF PULSED ELECTROMAGNETIC ENERGY (DIAPULSE) IN SURGICAL AND TRAUMATIC INJURIES OF THE MOUTH AND JAW. Lord C. Rhodes, Rhodes Dental Clinic, Norfolk, Va. 23501

Pulsed high peak power electromagnetic energy (Diapulse), operating at the following parameters; 27.12 megahertz, 400 to 600 PPS, 65 microseconds per pulse, and 585 to 975 peak watts, was adjunctively applied to 4500 dental patients over an eleven year period, resulting in a statistically significant reduction of hemorrhage, edema and pain. Healing was remarkably accelerated. Application was simple and safe. No contraindications of any kind were observed during the eleven year period. Three traumatic and three surgical injury case histories are presented, representative of the beneficial effects obtained from treatment.

D-11 NEURONAL REGENERATION STIMULATED BY PULSED ELECTROMAGNETIC FIELDS (PEMF) Betty F. Sisken, Bruce McLeod*, Scott Estes* and Richard Kryscio*, University of Kentucky Lexington, KY 40506 and Montana State University, Bozeman, MT 59717

Significant stimulation of neuronal regeneration after 6 days in vitro is obtained when sensory ganglia are subjected to single pulse electromagnetic fields (PEMF). Since the vertical orientation of the Helmholtz coils yields differing spatial distribution of induced fields (and hence current density), we directed our studies to determine if the degree of neurite outgrowth was correlated with the position of the ganglia in the dish. Similar experiments were performed in control dishes and in dishes treated with nerve growth factor (NGF) or direct current. The data obtained on 174 ganglia subjected to the 4 different treatments showed no statistical difference (paired t test) between ganglia located in the middle of the dish and those in the outer portions of the dish in any of the treatment groups. The Fourier spectrum of the PEMF signal was examined. It was found that the induced field pattern in space does not vary significantly with frequency up to at least 100kHz. We conclude therefore, that the major effect on the ganglia is probably due to frequency-related components of the signal at the lower end of the spectrum (less than 100kHz). This is consistent with several other recent reports. The single pulse signal may not have enough information content at the lower frequencies to produce a response that is related to position, or it may be that the neuronal cells are responding to the magnetic field component. Supported by the Office of Naval Research.

D-12 INTRAORBITAL HYPERTHERMIA WITH EXTERNAL MICROWAVES: DOSIMETRY AND THERAPEUTIC APPLICATIONS. Kenneth H. Luk*, Chung Kwang Chou, Arthur W. Guy. Department of Radiation Oncology and Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

There are a few tumors which involve the human eye, but the impact of visual dysfunction to a patient is immense. Such examples include malignant melanoma, rhabdomyosarcoma, retinoblastoma, and metastatic cancers. Dosimetry problems and limitations in hyperthermic treatment planning include encasement of the organ by bone, fluid contents of the eye, sensitivity of the cornea and lens, and critical brain tissues behind the eye. Interstitial applications of hyperthermia can deliver the required temperature to specific regions of the eye, but it has the disadvantage of being a major anesthetic and surgical procedure. In this paper, we present experiments in phantoma constructed of pediatric and adult human skulls and tissue equivalent materials, utilizing near field microwaves. Detailed mapping is done using simultaneous recording of temperatures at multiple points by way of the computer soft-ware program of the BSD 1000 unit. The significance of this research is in the search of a practical method of hyperthermia of the eye which can be reliably reproduced and given at most major medical centers.

SESSION E Neurological Effects

***Cochairs:* Hans-Arne Hansson and S.K. Dutta**

E-1 RESULTS OF EXPOSURES OF APLYSIA PACEMAKER NEURONS TO ELF/60 Hz AND DC MAGNETIC FIELDS. A.R. Sheppard, M.L. Burton* and W.R. Adey. VA Medical Center, Loma Linda and Department of Physiology, Loma Linda University, School of Medicine, Loma Linda, CA 92357.

Intracellular recordings were made of the spontaneous electrical activity of regularly firing neurons of the Aplysia abdominal ganglion during exposure in vitro to static, ELF or 60 Hz magnetic fields of up to about 10^{-2} T (100 Oe). The magnitude of the induced electric field is proportional to frequency and to depth of the liquid, whose surface is parallel to the H-field. At 60 Hz (sine wave) in our system, the induced E-field (about 3×10^{-5} V/cm rms) is much less than the minimal electric fields (about 5×10^{-4} V/cm rms) found effective in altering firing rate during exposure of Aplysia neurons to ELF current densities generated by electrodes, thus providing a test for H-field effects with minimal E-field. Results of exposures to dc, slowly ramped dc, square wave and sinusoidal waveforms at ELF/60 Hz were analyzed for alterations in temporal properties of the time series represented by the sequence of interspike intervals. So far, no effects of the magnetic field have been observed. (Research support by Department of Energy and Southern California Edison Company.)

E-2 MICROWAVE EXPOSURE INCREASES LATE OUTWARD CURRENT IN VOLTAGE-CLAMPED APLYSIA NEURONS. C. L. Brandt*, N. L. Campbell, and M. C. McEuen*, Bioengineering Branch, Navel Ocean Systems Center, San Diego, CA 92152.

Individual neurons of Aplysia visceral ganglia mounted within a temperature controlled microweve strip-line were voltage-clamped neer their resting potentiel (V_r). A number of series of brief voltage steps to levels ebove and below V_r were applied et verious times before, during and after exposure to 2.45 GHz energy. Current-voltage (I/V) plots for the late outward current at each voltage step were constructed. These I/V plots indicate that following an initial 40 to 60 minute period of fluctuation, the late outward current in control cells tends either to stabilize or to undergo e decrease of up to 10% with the passage of time (120-180 min.). However, after srebilization, the late outward current of neurons exposed to 2.45 GHz CW energy shows an increase of 10 to 30%. Following exposure, the late outwerd current often returns to the same velue as before exposure. Since the late outward current in molluscan neurons is carried by K^+ ions moving through voltage-gated and Ca^{++}-gated channels, microweve exposure must be increasing the conductance of these K^+ channels, either directly by altering the natural state of the channel, or indirectly by causing an increase in intracellular Ca^{++}. A microweve-induced increase in K^+ conductance can explain the inhibition of firing frequency we have observed earlier in some Aplysie neurons and is consistent with the microweve-induced decreese in membrane resistance of Helix neurons observed by Arber.

E-3 ROLE OF EXTERNAL CALCIUM IN MICROWAVE-INDUCED SNAIL NEURON RESPONSE. S.L. Arbar and J.C. Lin. Department of Bioengineering, Univarsity of Illinois, Chicago, IL 60680

We had prsviously reported that exposurs of snail nerve cells to 2.45 GHz causes a decreass of membrane rssistance. It has bssn suggested that such a dscreass of membrane resistance is associated with an increass of intracsllular concentration of free calcium releassed from intracellular stores. However, such a rise of calcium concentration can rssult from an increase of membrans psrmeability to external calcium ions. To check this possibility, we carried out two sets of experiments at 21°C: 1) irradiation of cells perfused by a Ringer solution with added Cd^{++} (0.9 mM) which is a good blocker of calcium msmbrane channels, and 2) irradiation of cells perfussd by Ringer saline with a reduced calcium ion concentration (1/10). In both cases, we observed a decrease of the input resistance after exposure at SAR 12.9 mW/g. In expsriments with added Cd^{++}, ths fall in membrane resistance was about 10%. In sxperiments with reduced Ca^{++}, the index, bassd on the relative change of membrans resistance for control and irradiated neurons, was 0.50 and 0.14, respectively.

E-4 A SYSTEM FOR RECORDING MICROWAVE EFFECTS ON ISOLATED MAMMALIAN BRAIN SLICES. G. R. Adey, B. L. McNaughton, and H. Wachtel. Departments of Electrical Engineering, and Psychology, University of Colorado, Boulder, CO 80309.

In recent years isolated slices from ths mammalian (rodent) brain have been used extensively to study basic neural mechanism and thsy can also be used advantageously to study microwave effects on neural function. Howevsr, the maintenance of vertebrate brain slices for neurophysiological recording purposes requires that temperature, O_2 CO_2 concentration, chamber humidity, and the depth and flow rate of the perfusate be delicately controlled. As a consequence of thess requirements, our existing microwave exposure system had to be substantially modified due to the physical constraints it forced on the tissue chamber's geometry. For the modified version, a TEM cavity was constructed around a working Haas brain slice chamber. This leads to a cavity of complex geometry which results in a nonuniform field. Careful mapping of the energy distribution in ths tissue chamber has shown that deposition occurs in a small but well defined area, and that much of the chamber is ssentially unexposed. This allows us to expose individual slides in the "hot" area of the chamber while maintaining other slices in an unexposed reserve.
Supportsd by ONR Contract N0017-81-K-0387

E-5 **CHANGES IN EVOKED POTENTIALS FROM HIPPOCAMPAL SLIDES EXPOSED TO WIDE MICROWAVE PULSES.** G. R. Adey, and H. Wachtel. Department of Electrical Engineering, University of Colorado, Boulder, CO 80309.

Our previous experimental studies (of Aplysia neurons) as well as theoretical considerations have led us to believe that "wide" microwave pulses (from 0.1 to 100 *milli* seconds) might be optimally effective in modulating neural activity with minimum energy input. We have seen further evidence of this in the behavioral responses of intact mice and, currently, in the modification of evoked potentials in isolated rat brain (hippocampal) slices. 400 micron thick slices of hippocampus were exposed to single microwave pulses (2450 Mhz, 4 msec, SAR 20-60 W/gm). At all power levels tested the preparation potentiates slowly following the exposure and reaches a stable elevated activity within 15 min. At SAR's above 30 W/gm an initial depression lasting 30-90 sec. preceeds the potentiation. These results are particularly intriguing since the temperature rises associated with these pulses are only 0.02 to 0.04° C – well below spontaneous temperature fluctuation levels in the brain.
Supported by ONR Contract N0014-81-K-0387.

E-6 **FIELD DETECTION AND THERMAL RATE MODELS FOR EXPLAINING NEURAL EFFECTS OF WIDE MICROWAVE PULSES.** H. Wachtel, and F. S. Barnes. Department of Electrical Engineering, University of Colorado, Boulder, CO 80309.

Our experimental results using wide microwave pulses (WMP) to elicit neural and behavioral responses indicate that, for a given pulse energy, changing the pulse duration significantly alters the effect. This phenomenon cannot be explained in terms of total temperature rise (which is the same for equi-caloric pulses) but can be predicted by models based on field detection or thermal rise rate mechanisms. These two classes of models both lead to duration dependent effect levels for equicaloric pulses, but the nature of this dependency is distinctly different in each case. By comparing the curves derived from each of these models to the experimentally generated curve it is possible to determine which is the dominant mechanism. There are also several putative mechanisms that could lead to temperature rate ($\dot{T}$) dependence; including microthermal and electrochemical equilibrium effects. Models based on these separate possibilities also lend themselves to experimental validation or refutation.
Supported by ONR Contract N0014-81-K-0387.

E-7 EFFECTS OF 60 AND 5 Hz ELECTRIC FIELDS ON NEURONAL EXCITABILITY IN RAT HIPPOCAMPAL SLICES. S.M. Bawin, A.R. Sheppard, M.D. Mahoney* and W.R. Adey. Dept. of Physiology, Loma Linda University & VA Hospital, Loma Linda, CA 92357.

Extracellular evoked responses were studied before, during and following stimulation with electric fields (10 - 50 mV/cm, p-p) applied to the physiological solution perfusing the slices. Both 60 and 5 Hz fields (5 - 10 s) were capable of inducing long lasting (10 m to hrs) increase of the synaptic response. However, the transient (1 - 6m) decrease in excitability that often followed stimulation at 60 Hz was not observed after exposure to 5 Hz fields. This frequency dependent plasticity of the response was confirmed in a series of experiments in which the fields were applied for longer periods of time (1 - 3 m). Progressive potentiations occurred during stimulations at 5 Hz and persisted for the life of the slices. By contrast, the short-lived excitations seen at the beginning of 60 Hz field epochs were followed by depressions which lasted for several minutes after the end of stimulation. The fields also induced short-term decrease in the antidromic response of the neurons, studied in the absence of synaptic transmission (0.2 mM Ca^{2+} and 4 mM Mg^{2+} in the perfusing solution). These results suggest that the depression induced by 60 Hz fields is independent of presynaptic mechanisms. (Supported by Department of Energy and Southern California Edison Company).

E-8 *EFFECTS OF ELF FIELDS BETWEEN 1 AND 120 Hz ON THE EFFLUX OF CALCIUM IONS FROM BRAIN TISSUE, IN VITRO.* C.F. Blackman, S.G. Benane*, W.T. Joines and D.E. House*. Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711.

We have shown that 16-Hz sinusoidal, electromagnetic fields can cause enhanced efflux of calcium ions from chick brain tissue, in vitro, in two intensity regions centered on 6 and 40 Vp-p/m (2.1 and 14.1 Vrms/m). Subsequently, we demonstrated that a 45-Hz field exhibited a similar intensity response around 40 Vp-p/m, while a 50-Hz field exhibited a somewhat narrower effective intensity region. We now demonstrate that there is no enhanced efflux associated with a 42-Hz field at 30, 40, 50 or 60 Vp-p/m, thereby emphasizing the distinct frequency-specific nature of the responses. Examination of the 16-Hz and 45-Hz intensity responses revealed that 42.5 Vp-p/m (15 Vrms/m) was the apparent center of the effective intensity region. We have now examined the effects of fields of this intensity at frequencies between 1 and 120 Hz. The results are presented as frequencies (p values): 1 (0.490), 15 (0.004), 30 (0.120), 45 (0.003), 60 (0.024), 75 (0.006), 90 (0.035), 105 (0.002), 120 (0.342). The results indicate that odd multiples of 15 Hz are particularly effective in producing enhanced efflux, while 60- and 90-Hz fields do produce statistically significant changes. We hope these results will assist in the development of models that will lead to a definitive mechanism of action.

E-9 STUDIES OF A FEW FACTORS CONTROLLING 915 MHz MICROWAVE INDUCED $^{45}Ca^{2+}$ EFFLUX FROM HUMAN NEUROBLASTOMA CELLS IN CULTURE. S.K.Dutta, B.Ghosh, A.Subramoniam and R.Parshad. Departments of Botany and Pathology; and Cancer Research Center, Howard University, Washington, D.C. 20059.

We have reported previously that 915 MHz radiation, sinosuidally amplitude modulated at 16 Hz, could induce an increase in $^{45}Ca^{2+}$ efflux from human neuroblastoma cells in culture at two narrow ranges of SAR 0.05 and 1.0 mW/g. These studies were extended to determine the influence of three additional factors on the microwave-induced calcium-ion effluxes. Observations using 915 MHz, 16 Hz AM, were as follows: (1) Effects of variation in depth of amplitude modulation. Radiation-induced $^{45}Ca^{2+}$ efflux at an SAR of 0.05 mW/g occurred at 60 or 80% AM but not at 0,20,40 or 100% AM. At an SAR of 0.1 mW/g enhanced efflux occurred at 0 or 20% AM but not at 40 to 100% AM. At an SAR of 1.0 mW/g enhanced efflux occurred irrespective of the depth of amplitude modulation. (2) The $^{45}Ca^{2+}$ content in the microwave exposed cells was found to either increase or decrease depending on the exposure period, as compared to respective controls. (3) Radiation-induced calcium efflux was specific for cells derived from the central nervous systems of human or mice. There was no radiation-enhanced calcium efflux from normal human skin fibroblast cells when tested at the power level SAR 0.05 mW/g using carrier frequencies 450,147 and 50 MHz, and at several power levels using 915 MHz as carrier frequency. Supported in part by an EPA grant and an institutional grant from NIH.

E-10 UNITARY ACTIVITY OF THE CRAB STRETCH RECEPTOR MODIFIED BY LOW INTENSITY ELF MAGNETIC FIELDS. José M.R. Delgado, and Julian Bustamante. Centro "Ramón y Cajal," Madrid 34, Spain.

Unitary activity of the tonic stretch receptor of the river crab was recorded in the dorsal nerve by means of microelectrodes connected to suitable filters, amplifiers, and tape recorder. The signals were processed in a PDP 11/40 computer to obtain histograms of first order intervals, autocorrelation, and crosscorrelation. Spontaneous activity of the receptor was controlled by stretching the muscle. Magnetic stimulation consisted of trains of pulses (0-30 Hz) with rising phase of less than 1 usec. Intensities were 0-100 uT. Results were as follows: (a) Pulsated magnetic fields did not modify the spontaneous discharge frequency of the receptor although some MF frequencies seemed effective. (b) Regular pulsated MF increased the regularity of receptor discharges while irregular fields induced irregularity in discharges. (c) At specific frequencies there was synchronization between neuronal discharges and pulsated MF. This relationship was observed for both regular and irregular MF. (d) Pulsated MF increased the silent phase produced in the receptor by mechanical overstretching. (e) The stretch receptor unitary activity of the crab has considerable sensitivity to MF which is demonstrated at intensities below 100 uT. (f) Unitary activity of the crab stretch receptor seems a good model for investigation of the parametric effects of MF and for their mechanisms of action.

E-11 ULTRASTRUCTURAL STUDIES OF MICROWAVE IRRADIATED SNAIL NERVE CELLS. J.P. Neilly, V. Kriho, Department of Anatomy, and S.L. Arber, J.C. Lin, Department of Bioengineering, University of Illinois, Chicago, IL 60680.

This atudy ia aimed at possible correlations between microwave-induced changes in electrophysiological properties of snail nerve cells and their ultrastructure. Two sets of experiments were conducted on subesophageal ganglia of Helix aspersa snails (16 animals), one at 21° C and another at 8° C. Snail neurons were exposed to 2.45 GHz at SAR 12.9 mW/g for 1 hour in a waveguide exposure system especially designed for cellular electrophysiological investigations (Lin, Arber, 1982). The temperature of the perfusing saline waa maintained constant in both sham and exposure experiments. After irradiation the brain was fixed in 4% glutaraldehyde in 0.1 M cacodylate buffer (pH 7.4) with postfixation in 1% osmium tetroxide, prepared in the same buffer and stained in bloc with 0.5% aqueous uranyl acetate. The brain was then dehydrated using ethanol and embedded in epon 810. Ultrathin sections were cut, stained with uranyl acetate and lead citrate and viewed under the electron microscope. No obvious morphological differences could be seen in the irradiated cells as compared with sham exposure.

E-12 EFFECT OF PULSED 3.07 GHz FIELD ON THE NERVOUS SYSTEM. BIOCHEMICAL, IMMUNOHISTOCHEMICAL AND HISTOPATHOLOGICAL STUDIES.

Hans-Arne Hansson, Björn Rozell, Nils-Gunnar Svennung and Lennart Persson, Institute of Neurobiology and Department of Neurology, Medical Faculty, University of Göteborg, P.O.B. 33031, S-400 33 Göteborg, Sweden.

The aim of the present study was to examine if it could be documented that microwaves cause affection of the nervous system of living animals. Rabbits were exposed for one hour to microwaves, directed against the right part of the brain (3.07 GHz, 300 Hz, pulse-length 1.4 ms, 55 mW/cm^2, SAR of the retina about 30 W/kg). The exposure period was 1 hour per day for three consecutive days. Thereafter the exposed rabbits and sham-exposed controls were kept in the animal house until day of sacrifice. Glial reaction was possible to demonstrate in the cerebellum, hippocampus, thalamus and hypothalamus. The retina and the primary optic pathway also showed glial reactions. Immunochemical analysis revealed an increased amount of the glial-specific protein S-100 as evaluated per wet weight and protein content. The Purkinje nerve cells showed immunoreactivity for neurofilaments after microwave exposure, in spite of the fact that it was lacking in controls. HPLC analyses of amino acid pattern have been performed in the cerebellum to further evaluate affection of neurotransmittors. Biochemical analysis of soluble proteins revealed a changed pattern for exposed animals as compared to controls. It is concluded that microwaves affect the nervous system to a larger extent than previously known.

E-13 INTERACTIONS OF ETHANOL AND MICROWAVES ON THE BLOOD-BRAIN BARRIER.
Joseph P. Neilly and James C. Lin. Department of Bioengineering, University of Illinois, Chicago, IL 60680

We have studied the interaction of ethanol and microwave-induced permeation of the blood-brain barrier. Male Wistar rats (450-550 g) were aneathetized with pentobarbitol (60 mg/kg i.p.) and cannulated in the left femoral vein. The rats were then infused with 0.1, 0.3, 0.5, or 0.7 g of 100% ethanol per kg of body weight. The control group was given 0.7 g/kg of isotonic saline. The left hemispheres of their brains were irradiated with microwaves at 3.15 GHz and 3.0 W/cm^2 net power for 15 min. The animals rectal temperature was kept at 37.0°C. Immediatly after the irradiation period 2% Evans blue in saline (2.0 ml/kg body weight) was injected (as a visual tracer of permeation of the blood-brain barrier) through the cannula. Five minutes after injection of the Evans blue, the animals were perfused transcardially, with saline followed by 10% buffered formalin. The brains were removed and inspected for degree of staining. It was found that the saline control group and the experimental groups receiving lesser quantities of ethanol showed heavy staining in the irradiated areas of the brain. However, as the quantity of alcohol was increased the degree of staining was decreased or eliminated. This data indicates that ethanol inhibits microwave-induced permeation of the blood-brain barrier.

SESSION F Instrumentation/Exposure System

Cochairs: Kjell H. Mild and J. Patrick Reilly

F-1 USE OF FLUOROPTIC™ THERMOMETRY DURING NUCLEAR MAGNETIC RESONANCE. R.V. Alves* and K.A. Wickersheim. Luxtron Corporation, 1060 Terra Bella Avenue, Mountain View, CA 94043

Fluoroptic™ thermometry, a phosphor-based fiberoptic temperature measurement technique, was developed primarily for use in high voltage and high rf field applications. Recently interest has developed in its use for temperature measurement during nuclear magnetic resonance (NMR) studies, principally of biochemical materials. Conventional NMR temperature determination involves the measurement of flowing air temperature outside the sample region. If the sample volume is small and the rf power high, substantial sample heating can occur quickly with little reflection in air temperatures. If the material being studied contains labile molecules, their structures can be altered by the sample heating thereby invalidating the data. Several NMR (and ESR) researchers have inserted the Fluoroptic probe into the sample volume during resonance to obtain more accurate and continuous knowledge of sample heating effects. In order to better understand the capabilities and limitations of the Fluoroptic system when used in such applications, we have made a number of measurements in the NMR environment with magnetic fields approaching 100 kilogauss. Both contact and noncontact sensing techniques were investigated with regard to resonance line broadening effects and magnitude of reading offsets produced by the dc magnetic field.

F-2 LOW FREQUENCY ELECTRIC AND MAGNETIC FIELD RADIATION MONITOR PROBES. Edward Aslan, Narda Microwave Corporation, Hauppauge, New York 11788

An isotropic magnetic field probe for the frequency region of .3 MHz to 10 MHz and an electric field probe for the frequency region of .3 MHz to 300 MHz are described. The equivalent power density range for both probes is 0.2 to 200 mW/cm^2. Thus permitting monitoring of the ANSI RFPG for that entire frequency range. The frequency sensitivity for the magnetic field probe is ± .5 dB. A ± 1dB sensitivity is provided for the electric field probe from 10 MHz thru 300 MHz. The 3 dB roll off occurs at .3 MHz for the electric field probe. The probes function in the square law region providing true summation of multipath signals and multiple frequency fields and independence of modulation. The orientation of the sensors is such as to eliminate errors in isotropicity caused by spatial shadowing. The magnetic field probe utilizes thin film thermocouple elements for the magnetic field and beam lead shotky diodes for the electric field probe. The lumped equivalent circuits, design and performance characteristics are described. Both probes are compatible with Narda's existing 8616 and 8611 metering instruments.

F-3 A MINIATURE BROAD-BAND MAGNETIC FIELD PROBE. Tadeusz M. Babij, Quirino Balzano, Doug Welsman*. Motorola Inc., Applied Research Laboratory, 8000 W. Sunrise Blvd., Ft. Lauderdale, FL 33322.

The objective of the work reported here is to develop a miniature broadband magnetic field probe capable of measuring the total magnetic field with a flat frequency response from 100 MHz to 1 GHz in near field of radiators. The probe consists of three loop antennas with zero-bias Schottky diode detector, and resistive parallel-wire transmission lines which transmit the detected signal from the diodes to the monitoring instrumentation. Special means have been developed for optimizing the frequency response, the antenna patterns and the rejection of undesired field components. The electric field pickup by the loop antennas is minimized through the use of specific techniques, and is less than -13 dB with respect to the magnetic field response, under equivalent free-space, plane-wave exposure conditions. Thin film technique construction provides repeatability and low cost for the probe. The theoretical results and experimental data are presented for prototypes tested over the 100 MHz to 1 GHz range.

F-4 UNIQUE RF (300 kHz-100 MHz) MAGNETIC FIELD STRENGTH MONITOR: PERFORMANCE CHARACTERISTICS AND INITIAL FIELD MEASUREMENTS. David L. Conover*, William E. Murray*, and Joseph M. Lary*. Division of Biomedical and Behavioral Science, National Institute for Occupational Safety and Health, Cincinnati, OH 45226; L.D. Driver* and J.E. Cruz*. Electromagnetic Fields Division, National Bureau of Standards, Boulder, CO 80303.

This paper discusses the performance characteristics of a radiofrequency (RF) magnetic field strength monitor developed for NIOSH by NBS and the results of initial field surveys with this monitor. The monitor has a dynamic range of 0.01 to 10,000 A^2/m^2, a frequency range of 300 kHz to 100 MHz, an isotropic response ($\pm$ 0.3 dB) due to three mutually orthogonal loop antennas, the ability to measure and display each of three orthogonal magnetic field components, a high probe burnout protection level of 20,000 A^2/m^2, and an accuracy of $\pm$ 1.0 dB at 14 calibration frequencies. The portable survey monitor was used to make the first on-site magnetic field strength measurements of occupational RF sources operating between 300 kHz and 5 MHz. Within this frequency range workers are exposed to several RF radiation sources including induction heaters. Initial magnetic field strength measurements made around induction heaters (operating below 5 MHz) are given.

F-5 CALIBRATION OF COMMERCIAL POWER DENSITY METERS AT RF AND MICROWAVE FREQUENCIES. Kjell Hansson Mild[1], Georg Nilsson*[2], and Ralf Boström*[3], Natl. Board Occup. Safety & Health, Umeå[1] and Stockholm[2], and FFV Maintenance Div., Arboga[3], Sweden.

In the fall 1982 a calibration was done of roughly 70 different probes from three different manufactures: General Microwave (Raham), Narda, and Holaday. The calibrations were performed at the frequencies 27 and 2450 MHz, respectively, and the power density levels used were in the range 10 - 100 W/m^2. The investigation was carried out at the Swedish Primary Calibration Center located at Arboga. The main purpose of the study was to make a comparison of the measurement accuracy of the commercial instruments most commonly occurring in Sweden. A considerable spread in values was found with regard to the absolute value of the indicated field strength as well as to the isotropicity of the probe. In many cases the values found were widely beyond the accuracy limits specified by the manufactures. Some instruments had an excessive meter zero drift which limits their usefulness. When the instruments are used to monitor potentially hazardous EM-fields in for instance the working environment it is of outermost importance that the user takes into account the imperfections of the instruments as indicated in this study. These results also point to the necessity of a regularly recurrent and relatively frequent calibration of the instruments.

F-6 A LIQUID FLOW CALORIMETER FOR USE IN EXPERIMENTAL MICROWAVE DOSIMETRY. Daniel J. Schaefer, Steven M. Sharpe*, and Juan G.Herrans*. Biomedical Research Division, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, GA 30332.

Flow calorimetry holds promise for measuring power absorbed by experimental animals in complex fields. Determinations of power absorption are made from steady-state measurements of the difference between the upstream and downstream temperatures in a fluid making thermal contact with the animal. The animal is placed in a sealed chamber surrounded by a microwave transparent fluid (paraffin oil) so that the ambient field is minimally perturbed. This configuration prevents evaporative thermal losses from the animal which may occur if a gas in direct contact with the animal was used as the fluid. Much lower volume flow rates are feasible when using a liquid instead of a gas as the working fluid. Successful analytical attempts have been made to predict the steady state differential temperature from early data on the heating curve. This is achieved by modeling the curve with an empirical equation and using values of the slope, time, and differential temperature to obtain estimates of the ultimate steady state differential temperature at successive data points. Accurate estimates may be obtained in twenty percent of the time required to reach steady state. Analysis of thermistor temperature circuitry has resulted in methods for nearly eliminating even order deviations from linearity and reducing others. (Supported by U.S. Environmental Protection Agency under Contract No. 68-02-3485)

F-7A 35 GHz, FM-CW SYSTEM FOR LONG-RANGE DETECTION OF RESPIRATION IN BATTLEFIELD CASUALTIES. Joseph Seals*, Steven M. Sharpe*, Daniel J. Schaefer, and Michael L. Studwell*. Biomedical Research Division, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, GA 30332

A non-contact, EM-based lifeform monitor capable of detecting respiration from extremely long ranges (100 feet) is being developed. This device will be used in battlefield situations (e.g., a chemical warfare environment) in which access to casualties by medical-rescue personnel is limited. Operation of the lifeform monitor is based on detecting respiration-related body motions by measuring EM fields scattered by the body being evaluated. Program efforts have focused on development of methods for overcoming problems that limit the range of current EM-based techniques. In studies performed using non-optimal components, respiration (in upright and prone subjects) and heartbeat (in upright subjects) were clearly monitored from a range of 50 feet. Currently, a prototype lifeform monitor is being developed that features components and techniques specifically designed for this type of application. It is estimated that this prototype lifeform monitor will be capable of detecting shallow respiration in prone subjects from a range of several hundred feet.

This research is sponsored by the Naval Medical Research and Development Command through Office of Naval Research Contract No. N00014-82-C-0390.

F-8 IMPLANTABLE ELECTRIC FIELD PROBES - SOME PERFORMANCE CHARACTERISTICS. Maria A. Stuchly, Radiation Protection Bureau, Health & Welfare Canada, Ottawa, Ontario, Andrzej Kraszewski, Stanislaw S. Stuchly, George Hartsgrove, Dept. of Electrical Engineering, University of Ottawa, Ottawa, Ontario, K1N 6N5.

Implantable probes for measuring intensities of the internal electric fields in biological tissues at radio and microwave frequencies are critically important in experimental dosimetry. A recently developed computer-controlled scanning system for experimental dosimetry in the near field has been used to evaluate parameters of commercially available probes. Three probe models, namely, Narda 26088, EIT 979 and Holaday IMI-01 have been tested. The modulation characteristics obtained indicate that the sensitivity of the probes decreases by a factor of two as compared with the continuous wave at about 400 Hz for the Narda probe, and at about 700 Hz for the EIT probe. The signal-to-noise characteristics obtained in the frequency range 0 to 10 kHz show that optimal modulation frequency lies between 300 and 700 Hz. The sensitivity of the probes in the frequency range from 300 MHz to 3 GHz has been determined in free space and in tissue phantom material. The range of linear operation of the probes has also been determined.

F-9 MAGNETIC FIELD MONITORING WITH A PORTABLE DOSIMETER. T.S. Tenforde, A.B. Geyer*, T.Y. Fujita*, K.S. Bristol*, F.S. Goulding*, and T.F. Budinger. Biology and Medicine Division and Department of Instrument Science and Engineering, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

A portable magnetic field dosimeter has been developed that contains 3 thin-film Hall sensors along orthogonal axes, a programmable microprocessor-based logic circuit, and 4096 12-bit words of permanent and random access memory [Rev. Sci. Instrum. 53: 326-331 (1982)]. In initial field tests with this dosimeter, the magnetic induction (B) has been measured at operator-accessible locations in 7 facilities with high DC magnetic field levels. The largest values of B recorded at these facilities were: (1) Large aperture solenoid spectrometer, Stanford Linear Accelerator: 5735 G; (2) Kaiser Aluminum Test Facility, Permanente, CA: 570 G; (3) Tandem Mirror Fusion Reactor, Lawrence Livermore National Laboratory: 375 G; (4) 184-inch cyclotron, Lawrence Berkeley Laboratory: 190 G; (5) 76-inch cyclotron, University of California at Davis: 100 G; (6) Bevatron, Lawrence Berkeley Laboratory: 40 G; (7) 88-inch cyclotron, Lawrence Berkeley Laboratory: 30 G. Values of B in the control room areas of these facilities were less than 10 G. These tests have demonstrated the portable dosimeter's utility for the continuous monitoring of personnel magnetic field exposures. [Research supported by the U.S. Department of Energy under contract DE-AC03-76SF00098 with the Lawrence Berkeley Laboratory, University of California.]

F-10 ACTIVE ANTENNAS IN THE NEAR FIELD EMF MEASUREMENTS. Hubert Trzaska ITA, Techn.Univ., Wyspianskiego 27, 50-370 Wroclaw, Poland

The near field sensor usually contains a short antenna loaded by a diode. If use a RF wideband amplifier the diode instead it is possible to have more sensitive set. Because of the amplifier and necessary here battery the sizes of the probe increase. They are much bigger than in the Bowmans probe, they are comparable or less than in commercially available ones. The probe could be applied for EM environment measurements, eg. in hospitals, with the use of panoramic methods and the accuracy of measurements would be much better regarding to large sized antennas. Presented probes were used successfully for measurements of the EMF radiated by living bodies. More advanced construction is equiped with an amplifier of square law characteristics. The use of three perpendicular probes makes it possible to measure arbitraryly polarized fields. Readings of the EMF intensity, on the contrary to the diode probes, are here independent of kind and direction of polarization. The probe could be fed by transparent feeder or by coaxial one / while panoramic measurements /. The last one makes some distortions in the probe radiation pattern. The active probe makes good perspective for the near field power density measurements.

F-11 FAR-FIELD X-BAND EXPOSURE SYSTEM FOR CELL CULTURES. Li-Ming Liu and Stephen F. Cleary. Department of Physiology and Biophysics, Virginia Commonwealth University, Richmond, Virginia 23298 and Whit Athey, Bureau of Radiological Health, Rockville, Maryland 20857.

An anechoic chamber for the far-field exposure of cell cultures to X-band microwaves has been constructed having interior dimension of 35" wide x 26" deep x 76" high. The reflectance of the walls has been reduced by greater than 40 db by lining the chamber with Rantec microwave absorber. Temperature can be controlled from 5°C above ambient to 50°C with a maximum temperature variation of less than 0.5°C over any horizontal plane. Cells are exposed in 35-mm plastic culture dishes placed in 2-mm deep wells 90° apart in a circular 2-cm thick low density styrofoam turntable. During exposure, the turntable is rotated at 10 rpm and the direction of rotation reversed every 10-s to minimize the effects of an azimuthal variation in power density. Negligible scatter was detected between cell culture samples or from the turntable, support shaft, or incubator walls. At an incident 9.3-GHz power density of 10 mW/cm^2 maximum temperature and SAR differences of 0.4° and 2 mW/g respectively were detected in the culture medium at the position of the cell monolayer. The radial and depth distribution of the absorbed microwave field were also determined.

F-12 CYTOGENETIC EVALUATION OF HUMAN LYMPHOCYTES EXPOSED TO ELF FIELDS ASSOCIATED WITH HIGH VOLTAGE POWER TRANSMISSION LINES. Gordon Livingston,*[1] Indira Chatterjee,*[2] Kristine Witt,[1] and Om Gandhi.[2] Departments of Family and Community Medicine[1] and Electrical Engineering,[2] University of Utah, Salt Lake City, UT 84132

A study is underway to investigate possible cytogenetic effects of 60 Hz fields on PHA-stimulated human lymphocytes. Cytogenetic tests on the exposed and sham control cells include the measurement of chromosome breakage and the frequency of sister chromatid exchanges in first and second division cells, respectively. The electric field exposure system consists of a pair of carbon electrodes separated from the cell culture chamber and growth medium by an agarose gel. The gel provides a conducting salt bridge yet protects cells and media from reaction products that may form at the electrodes. A constant magnetic field is produced over the length and width of the exposure chamber by two perpendicular Helmholtz coils. The coils are driven 90° out of phase by an external circuit thereby producing a circularly polarized magnetic field in the plane of the electric field. The current in both circuits is monitored by a two-channel strip chart recorder. Cells are exposed to a current density of 0.03 mA/cm^2 and a magnetic field of 2 gauss. Results of experiments now in progress with this exposure system will be reported.

F-13 STUDY TO DETERMINE LONG-TERM RADIOFREQUENCY RADIATION EFFECTS ON 100 CANNULATED RATS: A STATUS REPORT*. J. Toler, Biomedical Research Division, Georgia Institute of Technology, Atlanta, GA, 30332, and V. Popovic, Department of Physiology, Emory University School of Medicine, Atlanta, GA, 30322

There is a continuing concern with the possibility that long-term exposure of biological systems to low-level radiofrequency radiation (RFR) might induce hazardous effects. To investigate this possibility, a research program has been initiated to continuously expose 100 male Sprague-Dawley rats for six months to a 1.0 mW/cm^2 435-MHz RFR environment generated by a four-tier circular parallel-plate antenna located in a shielded, anechoic test chamber. The rats are housed in specially-designed Plexiglas cages spaced one wavelength apart. Another 100 sham-exposed rats are housed in an identical facility in an adjoining chamber. Each rat has a PE 10 cannula implanted in the left common carotid artery, thereby making circulating arterial blood accessible in unrestrained, unanesthetized animals. Blood microsamples drawn from the cannulae at specified intervals are assayed for hormones and blood chemistry. Also, a standard blood series is conducted and, in a subset of the rats, hormone assays are conducted in excersizing rats. The status of this study, including experience with the exposures and any initial assay results, will be presented.

*This research is sponsored by the Air Force School of Aerospace Medicine under Contract No. F33615-83-K-0600.

SESSION G Poster Papers I

Chair: Frank Barnes

GJ-1 THE LEVER-PRESSING OPERANT AS A CUED OR UNCUED ESCAPE RESPONSE OF kATS MOTIVATED BY INTENSE MICROWAVE RADIATION. D.W. Riffle,* D.M. Levinson, and D.k. Justesen. USVA Medical Center, Kansas City MO 64128, and Univ. of KS School of Medicine, Kansas City, KS 66103.

A systematic series of studies in our laboratories of motivational properties of intense microwave (MW) fields has largely been based on locomotor escape behaviors of experimentally naive mice and rats. In the study summarized here, seven experimentally sophisticated rats performing an operant lever-pressing response were assessed for escape responding, both with and without collateral sensory cueing by a field-synchronous photic stimulus. During 19 10-min. sessions at an ambient temperature of 25 $\pm$0.5 ^{o}C, each operant response by a rat extinguished or precluded activation of an intense, 2450-MHz field (60 mW/g) for 12 seconds. Without photic cueing (7 sessions), the animals extinguished the field 49% of the time; with the photic cue (12 sessions), 58% of the time ($P < .001$). Respective post-session means of colonic temperature reveal a small but highly reliable ($P < .001$) difference: 40.5 ($\pm$0.057SE) vs. 40.0 ($\pm$0.065SE) ^{o}C. The schedule of escape responding employed in this experiment gave the rats the opportunity not only to escape from, but to <u>avoid</u> MW irradiation. Avoidance behavior was not observed, but highly stable escape responding was, which in combination indicate that brief bursts of intense MW irradiation are without negative affect and might be positively reinforcing in a cool--for the rat--environment.

GJ-3 INFLUENCE OF MICROWAVE DOSE RATE AND AMBIENT TEMPERATURE ON ESCAPE BEHAVIOR OF RATS. D.M. Levinson, D.W. Riffle,* and D.R. Justesen. USVA Med. Ctr., Kansas City MO 64128; Univ. of KS School of Medicine, Kansas City KS 66103.

In extending work on the lever-pressing operant as an escape response by experimentally sophisticated rats under motivation by intense 2450-MHz microwaves (MWs), we performed two studies (all based on 10-min. sessions): One (Exp. I) involved three dose rates of irradiation (60, 90, or 120 $\pm$10% mW/g) at an ambient temperature of 25 ($\pm$1) ^{o}C; and one (Exp. II) involved three ambient temperatures ($\bar{X}$s of 17, 25, or 34 $\pm$1 ^{o}C) and a dose rate of 60 $\pm$10% mW/g. In both studies, a photic cue accompanied activation of the MW field. Ambient air velocity was 0.3 m/s (RH < 30%). In Exp. I, rats respectively extinguished the field 58, 65, and 74% of the time ($P < .05$); associated means of post-session colonic temperature are 40.0, 40.4, and 40.5 ^{o}C ($P > .05$). In Exp. II, a partial replicate based on the same 7-9 animals, the rats respectively extinguished the field 52, 58, and 64% of the time ($P < .05$); associated post-session means of colonic temperature are 39.9, 40.0, and 40.2 ^{o}C ($P > .05$). These data provide evidence that brief bursts of intense MW irradiation result in neutral or positive affect, and that longer bursts can motivate escape. The data also reflect both earlier-incrementing and later-stabilizing colonic temperatures during brief periods of testing. Only prolonged sessions of scheduling ($\sim$60 min.), items on the future agenda of research, can reveal whether the rats will thermoregulate at "preferred" levels of body temperature.

GJ-5 HYPOTHALAMIC TEMPERATURE OF RATS EXHIBITING OPERANT CONTROL OF AN INTENSE MICROWAVE FIELD. D.M. Levinson, D.W. Riffle,* and D.R. Justesen. USVA Med. Ctr., Kansas City MO 64128, and Univ. of KS School of Medicine, Kansas City KS 66103.

Two rats, each with a cannula stereotactically implanted in the brain (target aree: preoptic hypothalamus), were observed for operant lever-pressing behavior by which they controlled inactivation of en intense (60-mW/g) 2450-MHz microwave field. A photic cue was presented in temporal synchrony with the field. During an extended series of deily, 10-min. sessions, each depression of the lever extinguished (or delayed activetion of)the field for 12 s. Brain temperature was measured continuously during sessions by a Vitek or Luxtron non-perturbing probe. Typically, during initial 60- to 70-s periods of irradiation, brain temperature rose by $\sim$1 ^{o}C before the animals--previously well trained in the operant task--began to depress the lever at a rate near 3.5/min. Early on, during the 12-s periods of operant inactivation of the field, temperatures fell by $\sim$0.10 ^{o}C; then, with automatic reactivation of the field, temperatures rose by $\sim$0.16 ^{o}C before succeeding depressions of the lever. Later, about midway through a session, peak temperetures reached esymptote, and successive + and - ΔTs approached parity near 0.2 ^{o}C, reflecting highly stable, regularly paced responses at the lever. In contrest to pre-exposure beselines of brain end colonic temperature ($\bar{X}$ = 38.3 and 38.1 ^{o}C), means of temperetures measured immediately after the 10-min. sessions are, respectively, 40.8 end 40.2 ^{o}C.

GJ-7 LECTINS MITOGENIC EFFECTIVENESS ON HUMAN LYMPHOCYTES IS DEPENDENT ON THE FREQUENCY OF ELECTROMAGNETIC (EM) EXPOSURE. A. Chiebrera[a], G. Bonanno[b], G. Giennetti[c], M. Grettarole[a], A. Raveene[c], R. Viviani[c]. [a]Biophysicel and Electronic Engineering Division, Electronic Engineering Dept., University of Genoa, 16145 Genoa, Italy. [b]Phermecology Dept., University of Genoa, 16132 Genoa, Itely.

The biologicel effects of the interactions emong lectins, their receptors on humen lymphocytes end em exposure have been experimentelly proved in our laboretories since 1980 [1]. The aame waveform [2] as adopted in clinicel practice for treating bone frectures proved to decrease lectin mitogenic effectiveness. We have devised e simplified theory [3] which is in qualitetive agreement with this result. The theory predicts thet, if e simpla sinusoidel waveform is used, the antagonistic effect of the field will be inversely releted to the frequency of the signel, except for frequency values equal to the inverse of the mean lifetime of lectin-receptor eggregetes, for which the effect should disappeer completely. If the theory is eppliceble, the method should offer e way of meesuring such a lifetime. Experiments with sinusoidel waveforms ere in progress in our leboretories end the discussion of the results so fer obteined will contribute to corroborate the theory.

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[2] M. Grattarole et al., Studie Biophysice, 91, 117 (1982).
[3] A. Chiebrera et el., Bioelectromegnetics, in press, (1983).

GJ-9 INACTIVATION OF THE OXYGEN RADICAL GENERATING SYSTEM OF ERYTHROCYTES BY PULSED-WAVE 2.45 GHz THERMOGENIC RADIOFREQUENCY RADIATION. Johnathan L. Kiel* and David N. Erwin. USAF School of Aerospace Medicine, Brooks AFB, TX 78235

Thermogenic levels of radiofrequency radiation (RFR) were compared with conventional (hot air) heating for the ability to inactivate metabolic pathways that produce oxygen radicals and peroxides in erythrocytes. An immobilized luminol peroxidase system (BEMS Abstract I-13, 1982) was used to detect the generation of oxygen radicals and peroxides in Sprague-Dawley rat erythrocytes. The erythrocytes were heated to 44, 47, and 48 degrees C for 6, 20, 30, or 60 minutes, respectively, using a circularly polarized waveguide system or hot air with the final temperature matched to that of the RFR exposure. The cells ($1X10^9$) were suspended in 1 ml of phosphate buffered saline at pH 7.4 and exposed to 2.45 GHz pulsed RFR at an average power density of 5 mW/cm^2, SAR = 0.4 W/kg, and a duty factor of 0.01. Chemiluminescence of the RBCs induced by a second heating cycle and measured in a liquid scintillation counter, decreased following exposure to either RFR or conventional heating. Inactivation by either method produced results which were essentially the same, and exposure at non-thermogenic RFR levels at 37 degrees C produced no change from control (no RFR) levels. These results indicate that irreversible RFR effects on the metabolic pathways which maintain oxyhemoglobin, the principal source of oxygen radicals and peroxides in RBCs, are thermal in origin. (This work was supported in part by the U.S. Air Force Office of Scientific Research.)

GJ-11 HORIZONTAL GEOMAGNETIC FIELD AS AN INDEX OF IMMUNOCOMPETENCE OF DOGS. Robert F. Smith,[1] Moshe Shifrine,*[2] Don R. Justesen,[1] and Robert G. Garrison,*[1] ([1]USVA Medical Center, Kansas City, MO 64128) ([2]Univ. of California at Davis, 95616)

Based on a generalized least-squares analysis (GLS), counts based on whole-blood lymphocyte-stimulation tests (WB/LST) of 11 beagles by concanavalin A (Con A) and by phytohemagglutinin (PHA) were found to correlate positively with monthly averaged variations of the horizontal geomagnetic field (HGMF) (Con A $\underline{r}_z$ = .428 and PHA $\underline{r}_z$ = .356; both $\underline{Ps}$ <.05). Blood samples were obtained monthly from August 1977 through August 1981, which bracket a period of rising, then falling, sunspot activity. The dogs were from randomly bred stock and were maintained in outdoor pens. Further clarification of this correlation was sought by performing both the GLS and the non-parametric Co-Movement analyses for strength of synchrony between the WB/LST data and the HGMF in <u>individual</u> dogs. In five of the dogs, the apparent, HGMF-enhanced lymphocyte response is reliable for <u>both</u> mitogens ($\underline{Ps}$ < .05) as revealed by <u>both</u> analyses. Monthly means of temperature and precipitation are not contributive factors. Strength of the HGMF is inversely related to sunspot number by way of fluctuations in the solar wind. If the field-lymphocyte association is causal, we suspect that the HGMF is an intermediary in a complex chain of events that links the solar wind to immune reactivity, perhaps by modulating the density of the HGMF, which acts as variable shield to higher-energy photons (UV, X rays) that can affect the immune system. Alternately, the HGMF may act directly as a co-factor to modulate the immune response to mitogen.

GJ-13 TEMPERATURE MEASUREMENTS IN PREGNANT EWES EXPOSED TO RADIOFREQUENCY RADIATION. Jerome H. Krupp[1], Robert H. Carpenter[2], and John S. Hanson[1]. [1]Radiation Sciences Division, USAF School of Aerospace Medicine, Brooks AFB, TX 78235. [2]Univ. of Texas System Cancer Research Center, Bastrop, TX.

Ewes from 0 to 110 days of pregnancy were anesthetized and catheters implanted in uterine muscle, amniotic fluid or fetal tissue. They were exposed to radiofrequency radiation of varying frequency, intensity and polarization. Temperature measurements were made in uterine tissues via the catheters, the subcutaneous space over the ribs and in the colon. For whole-body penetrating radiation (219 MHz) the threshold for rise in deep colonic temperature was 32 mW/cm^2 (SAR = 6 W/kg). Thermoregulation kept colon, uterus, and skin temperatures below 41°C during a 90-minute exposure. Comparable SAR from exposure to 2.1, 2.8 or 9.3 GHz, produced a rapid rise in skin temperature leading to termination of the exposure, but with only minimal elevations in colon or uterus temperature. For the above exposures, the animals were in E-polarization. When K polarization was used for the GHz frequencies, the exposure could be extended to 1 hour, with a slow, sustained rise in deep colonic temperature, and to a much lesser degree in uterine tissue. Increasing the ambient temperature accelerated the colonic temperature rise, but had little effect on uterine values. Responses to pulsed or CW mode were comparable. It would be difficult to postulate a threat to pregnancy at current or proposed permissible exposure levels based on these data.

GJ-15 DEVELOPMENTAL TOXICOLOGY STUDIES IN HANFORD MINIATURE SWINE EXPOSED TO 60-Hz ELECTRIC FIELDS. M.R. Sikov, R.D. Phillips, R.L. Buschbom, D.N. Rommereim, and W.T. Kaune. Battelle, Pacific Northwest Laboratories, Richland, WA 99352.

Developmental toxicology and teratology were investigated in Hanford Miniature swine exposed to electric fields. One group (E) was chronically exposed to 60-Hz, 30 Kv/m electric fields; another group (SE) was sham-exposed. The F_0 gilts were bred after 4 months on study; some were killed for teratologic study at 100 days of gestation (dg) and the others produced an F_1 generation of offspring. Pooled incidence of F_1 litters with terata was similar in the E (40%) and SE groups (35%). The F_0 females which produced the F_1 generation were rebred 18 months later and killed at 100 dg; malformation incidence in E litters (75%) was significantly greater than in SE (29%). The F_1 gilts were bred at 18 months of age; defective offspring were found in significantly more of the E litters (71%) than in SE litters (33%). Teratologic evaluations at 100 dg were subsequently performed on second litters from this F_1 generation. The percentage of litters with malformed fetuses was essentially identical in the E and SE groups (70% and 73%, respectively). The change in malformation incidences between generations and between the first and second breedings makes it difficult to unequivocally conclude that electric field exposures cause developmental effects in swine although there appears to be an association. (Research supported by the Electric Power Research Institute)

GJ-17 SPERM MORPHOLOGICAL CHANGES IN MICE FOLLOWING MICROWAVE EXPOSURE. Chiang Huai, Wang Min* and Lou Yan*. Zhejiang Medical University, Hangzhou 310006 China

Forty eix mice (hybrid) in two groups were exposed to 2,450 MHz CW microwave in far field once for 30 min, paralleling H vector. The results revealed that the maximum incidence of eperm abnormalities (9.48±4.7%) occured in the high dose group (32 mW/cm^2, 12.8 mW/g) on the 5th week following exposure (control group, 2.2±0.99%). Thie indicated that the primary epermatocyte was more susceptible to microwave. Sperm abnormality rate in the high dose group returned to normal (2.75±1.7%) at 9th week following expoeure. An increase of sperm abnormality incidence (4.39±1.62%) was aleo revealed at lst week following exposure in the eame group, and was characterized by increasing in "plump head" type sperms. Theee reeults consist with our experiment on chromoeome aberration of testes in mice.

GJ-19 EFFECTS OF ULTRASOUND EXPOSURE ON THE HAMSTER IMMUNE SYSTEM. Ronald Johnston*, Charles Cain, and Wayne Tompkins*. Departments of Electrical Engineering and Veterinary Pathobiology, University of Illinois, Urbana, IL 61801

Ultrasound irradiation of the Hamster spleen with intensities which are used clinically for therapeutic diathermy and hyperthermia, caused significant reductions in Natural Killer (NK) cell activity as monitored by an <u>in vitro</u> cytotoxic assay. NK activity was reduced by 50% when the spleen was exposed to 5 W/cm^2 for 500 seconds (41.5°C). At 15 W/cm^2 and 150 seconds, NK activity was reduced by 75%. The minimum activity was observed four hours after irradiation and normal levels of activity were seen after 24 hours. Ultrasound exposure of the peritoneal cavity at 5 W/cm^2 for 900 seconds, followed by immediate intraperitoneal injection of Sheep Red Blood cells (SRBC), caused a 30% increase above control levels in the number of SRBC-specific antibody producing cells extracted from the spleen four days later. Regional heating to equivalent temperatures with 2450 MHz applicators did not produce similar results. These alterations in cellular and humoral immune function could be of significance to clinicians using therapeutic dia'hermy or hyperthermia where the path of the sound beam may impinge on these regions of the body.

GJ-21 EFFECTS OF MICROWAVE EXPOSURE ON THE HAMSTER IMMUNE SYSTEM. G. V. RamaRao, W.A.F. Tompkins, and C. A. Cain, University of Illinois at Urbana-Champaign, Urbana, IL 61801

Acute exposure of hamsters to microwave (MW) energy (2.45 GHz; 25 mW/cm^2; 1h) resulted in viricidal activstion of peritoneal macrophages and extended survival of hamsters injected with a lethal dose of vesicular stomatitis virus (VSV) one day after MW exposure. In one experiment, a lethal dose of VSV (5×10^3 plaque forming units/hamster) killed all sham exposed hamsters by 4 days (3.2 days mean survival time). In the irradiated group, 4 of 6 hamsters died (6.5 days mean survival time) while 2 hamsters survived beyond 20 days. Further experiments showed that peritoneal macrophages from microwave exposed hamsters restricted VSV growth (1.4 $\log_{10}$ unit increase in 24 hours) when challenged with VSV *in vitro* whereas VSV increased by 3.0-3.5 $\log_{10}$ units in normal hamster macrophages. In another experiment, hamsters were microwave or sham exposed and were injected with sheep red blood cells (SRBC) and their spleen cell antibody production against SRBC was measured using the hemolytic plaque sssay. The results showed highly significant increases in plaque production (300%) when the animals were exposed to microwaves (25 mW/cm^2) for one hour. Extended survival of hamsters from VSV injection could be due to activated macrophages destroying injected virus and perhaps to increased anti-VSV antibody production. These results are consistent with our previous work with vaccinia virus (Bioelectromagnetics, in press).

GJ-23 EVIDENCE THAT UV PHOTODESTRUCTION OF ACETYLCHOLINESTERASE IS A SUB-NANOSECOND PROCESS. William H. Bishop*, John P. Christopher*, and David B. Millar*. Naval Medical Research Institute, Bethesda, Maryland 20814.

EMR in the UV range (250-300 nm) rapidly inactivates the important neuroenzyme, acetylcholinesterase. Fluorescence spectroscopy demonstrates that this effect is dependent on electronic excitation of aromatic structures in the protein. To characterize the temporal features of enzyme destruction, the deactivation of the excited electronic state was examined. The collisional quencher, acrylamide, was studied for its relative abilities to (i) decrease fluorescence from the excited structures and (ii) protect the enzyme from EMR inactivation. An 85% reduction in fluorescence demonstrated that, within the nanosecond time-range, the quencher efficiently penetrates the protein matrix and depopulates the excited state. The interesting observation is that this great suppression of electronic excitation does not measurably protect the enzyme from inactivation by UV EMR. The conclusion is that the macromolecular structural fluctuations which limit the rate of enzyme inactivation must occur in times less than approximately 0.1-10 nanoseconds.

GJ-25 DIFFERENTIAL EFFECTS OF CONDUCTIVE AND RADIANT HEATING ON EVOKED POTENTIALS AND BRAIN TEMPERATURE. Virginia Bruce-Wolfe, Don R. Justesen, Donald W. Riffle,* and Stanley C. Gilbert.* USVA Medical Center, Kansas City, MO 64128; University of Kansas School of Medicine, Kansas City, KS 66103.

In Exp. I, female Long-Evans rats were implanted with small recording electrodes to vertex and to occipital cortex. Later, photically evoked potentials (EPs) of awake animals were summed and plotted before and after conductive (hot-pad) or radiant (2450-MHz-microwave) heating that resulted in elevation of colonic temperature to 41.5 °C. Mean latencies of EPs decreased under both modes of heating, but more so under irrsdistion. In Exp. II, rats fitted with cannulae (target area: preoptic hypothalamus) were observed for brain temperatures under pentobarbital anesthesia (30 mg/kg, IP) immediately before and immediately after elevation of colonic temperature to the 41.5-°C criterion by conduction or irradiation. Comporting with the Exp.-I finding of differential reduction of EP latencies is the finding that brain temperatures of irradiated rats (~43 °C) were significantly higher than those of conductively heated rats (~41 °C) at the criterion of colonic temperature. Greater depth of penetration by 12-cm microwaves and enhanced absorption by the head ganglion are presumptive factors in the observed differences, as is retarded circulatory convection borne of anesthesia. The role of anesthesia per se is under investigation.

GJ-27 EFFECTS OF EMF ON NEUROTRANSMITTER RELEASE. B.J. Vasquez, L. Deloff*, and W.R. Adey. Dept. of Pharmacology, Loma Linda University and VAMC, Loma Linda, CA 92357.

Experiments reported here measured in vitro release of catecholamines (norepinephrine and dopamine), an indicator of neuronal activity, from rat brain regions (striatum, hypothalamus, and hippocampus) exposed to microwave fields in a Crawford cell. The parameters under study were low level (1.0 mW/cm^2 pep) 450 MHz fields modulated at low frequencies (16 and 60 Hz). Unmodulated field exposure (CW) and SHAM groups completed the design. Values from each EMF condition were compared to appropriate control samples run in parallel in a 37°C incubator. The ratio experimental/control (X/C) was used as an index of change. Briefly, the technique involved incubation of freshly prepared minced brain tissue (10-50 mg) in a physiological solution at 37°C for 10 m. Field exposure was applied during this period. Catecholamine release from the tissues was then stopped by cold and acid treatment and the product immediately injected into an HPLC system in a 20 µl volume. Examination of the X/C ratios suggested a frequency related change in release levels. However, two-way ANOVA of the data showed no statistically significant F values for any of the variables (field condition and group) or their interaction. (Supported by Department of Energy, Bureau of Radiological Health, and Southern California Edison).

GJ-29 SPECTRAL CONTENT OF MICROWAVE-INDUCED AUDITORY STIMULI AS DEMONSTRATED BY [^{14}C]-2-DEOXY-D-GLUCOSE ([^{14}C]2DG) UPTAKE AT THE INFERIOR COLLICULUS. Blake S. Wilson∇, James B. Kobler*†, John H. Casseday*† and William T. Joines†. ∇Research Triangle Institute, RTP, NC 27709 and †Duke University, Durham, NC 27706.

Although thermoelastic expansion is generally accepted as at least one mechanism of "rf hearing" effects, the sites at which auditory stimuli are produced remain a matter of controversy. In the view of Chou et al., high-frequency oscillations they recorded at the round windows of guinea pigs and cats reflect intracranial reverberations of a pressure pulse induced within the brain. Results from single-unit and psychophysical studies indicate, however, that the frequency content of microwave-induced stimuli is broad, suggesting instead that thermoelastic expansion within the cochlea itself may be responsible for rf hearing effects. In the present work we used the [^{14}C]2DG method to map the patterns of metabolic activity evoked in the inferior colliculus of rats by 3 kHz and 30 kHz tones, acoustic clicks and 10-μs microwave pulses. The tones produced sharp bands in the central nucleus, the loci of which were consistent with the known cochleotopic organization of this structure. In contrast, acoustic clicks and microwave pulses produced nearly even increases in activity across the entire extent of the central nucleus, demonstrating, without electrodes of any kind, that the frequency content of microwave-induced auditory stimuli is indeed broad, and therefore that the site of initial stimulation is probably within the cochlea. (This work was supported by EPA contract 68-02-3276).

GJ-31 INTERACTION BETWEEN THE EFFECTS OF NON-IONIZING AND IONIZING RADIATION AT THE LEVEL OF SENSORY SYSTEMS. M.S.Burencov*, R.M.Salimov*, V.V.Engovatov*. Institute of Biophysics, Department of Health, Moscow, USSR 123182.

It is supposed that one of the possible mechanisms of the low level microwaves (MW) and ionizing radiation combined action may be the effect on skin receptor structures. It should be expected then that activation of this cutaneous 'input' will affect the state of the other modality 'inputs' particulary manifestating in the sensory reactivity alterations. It could be expected then that within certain limits the radiation wave length and power density will not be of a critical significanse. The hypothesis was tested in three series of experiments. When MW (0.9GHz CW, 0.4mW/cm^2, 10min exposure) and rhythmical photostimulation are simultaneously applied the rat's EEG following response to the rhythm of light flashes is significantly decreased. It was also found that MW (0.6GHz CW, 0.04mW/cm^2, 5 min exposure) and gamma quants (0.5Gr, single exposure) used separately before testing significantly delay the mice's jumping response from cooled floor (-2°C) while in the case of combined action no significant effect was found. In the next experiment was established that MW (9.8GHz CW, 0.04mW/cm^2, 5min exposure) does not affect the mice escape response from the swimming-pool with near comfortable water temperature(+22°C). The data are in agree with the initial hypothesis and may give additional facilities for elaboration of hygienic norms of non-ionizing and ionizing radiation combined action.

GJ-33 PHYSIOLOGICAL ABNORMALITIES IN JUVENILE AND ADULT JAPANESE QUAIL EXPOSED TO MICROWAVE RADIATION DURING EMBRYOGENY. M.J. Galvin, D.I. McRee, and J.P. Thaxton. Laboratory of Environmental Biophysics, NIEHS, Research Triangle Park, N.C. 27709

Fertile Japanese quail eggs were exposed to 2.45 GHz CW microwave radiation for the first 12 days of embryogeny to an incident power density of 5 mW/cm^2 (SAR = 4.03 mW/g). The exposed and non-exposed quail were 6 or 12 weeks of age for the hematological studies and 6, 12, or 22 weeks of age for the immunological studies. In the hematological studies, red blood cell numbers, packed cell volumes, totsl hemoglobin levels, and mean cell volumes were greater in the exposed group for both the 6 and 12 week old quail. Mean corpuscular hemoglobins and mean corpuscular hemoglobin concentrations were not changed. Mild hemorrhagic stress on experiment days 3, 6, and 9 produced no effects different from that of the control quail. These results indicate that microwave exposure during embryogeny causes increased numbers of RBC in adult quail, but had no effect on erythropoietic ability following mild hemorrhage. Additional quail were also evaluated for humoral immune responsiveness to chuker red blood cells, delayed hypersensitivity to phytohemagglutinin (PHAP), and total and absolute circulating levels of leucocytes. All parameters were equivalent in exposed and non-exposed controls at 6-weeks of age. However, in 12- and 22-week old quail, delayed hypersensitivity was reduced and a general leucocytosis was observed in exposed females. These data demonstrate that microwave exposure during embryogeny may produce latent effects which appear in adult quail.

GJ-35 EFFECT OF AVERAGE POWER LEVEL ON HEART RATE CHANGES DUE TO 5.6 GHz RADIOFREQUENCY RADIATION. James R. Jauchem*, Melvin R. Frei*, and Ferdinand Heinmets*. Technology Incorporated, San Antonio, TX 78216 and Trinity University, San Antonio, TX 78284.

During exposure of anesthetized rats to 5.6 GHz pulsed or continuous wave (CW) radiofrequency radiation (RFR) at 60 mW/cm^2, which resulted in a $1^{\circ}C$ increase in colonic temperature (Tc), heart rate increased significantly ($p < .05$) from 332 ± 7 (mean $\pm$ SEM) to 351 ± 6 beats/min (N=15). The values returned to control levels after exposure was discontinued. Exposure to pulsed or CW RFR at 30 mW/cm^2, with a $1^{\circ}C$ increase in Tc, did not result in any significsnt changes in heart rate (from 310 ± 5 to 310 ± 8; N=14). The time for Tc to increase by $1^{\circ}C$ during exposure at 30 mW/cm^2 was over twice as long as that during exposure at 60 mW/cm^2. There were no differences between heart rate results obtained during pulsed versus CW RFR. The data indicate that heart rate changes during exposure to 5.6 GHz pulsed and CW RFR are related to the average power level applied, and thus possibly to the rate of change in temperature, and not simply to the absolute change in temperature. (Performed at USAF School of Aerospace Medicine, Brooks AFB, Texas; USAF Contract #F33615-80-C-0614.)

GJ-37 PHYSIOLOGICAL THERMOREGULATORY CONSEQUENCES OF LONG-TERM EXPOSURE TO 2450 MHz MICROWAVES: SECOND REPORT. Donald E. Spiers*, Eleanor R. Adair, Philip J. Pivirotto*, and Barbara W. Adams*. John B. Pierce Foundation, New Haven, CT 06519.

Pairs of adult male squirrel monkeys were either exposed to planewave 2450 MHz CW microwaves at a power density of 5 mW/cm^2 (SAR = 0.75 W/kg) or sham-exposed. Each animal occupied a Plexiglas cylinder from 0830 to 1630 hrs, 5 days a week at an environmental temperature (T_a) of either 25°C (Group IV) or 30°C (Group V). Standardized physiological tests on each animal determined short-term physiological responses to different T_a challanges (range = 19-39°C) at four-week intervals during (4 tests) and after (2 tests) sham- and microwave-exposure. These tests included measurements of deep body temperature, four skin temperatures, metabolic heat production, and local sweating from the foot, with the results analyzed against extensive pre-exposure baseline data. Thermoregulatory responses of animals exposed to microwaves at 5 mW/cm^2 were not different from the responses, reported last year, in animals exposed to 1 mW/cm^2 at identical environmental temperatures. Normal acclimation to mild heat stress occurred in the 30°C environment, as evidenced by a slight reduction in metabolic heat production of both sham- and microwave-exposed animals. There was no experimental evidence to suggest that long-term exposure to microwaves alone, under these conditions, alters the thermoregulatory ability of the squirrel monkey. (Supported by EPA Grant CR807085010).

GJ-39 AN EFFICIENT ALGORITHM FOR ELECTROMAGNETIC IMAGING, M.J. Hagmann, BEIB/DRS, National Institutes of Health, Bethesda, MD 20205

We have previously described an algorithm allowing explicit non-interative solution for the local complex permittivity within an object by using values of the incident and scattered electric fields. A new algorithm will be described in which the size of the only matrix to be inverted is proportional to $\sqrt{N}$ rather than N where N is the number of permittivity values to be determined. The required computations with this algorithm are significantly less than for the forward problem with the same value of N. Use of multiple views has allowed the improvement in efficiency. The number of required external devices, such as dipoles, is proportional to $\sqrt{N}$. Each device is consecutively used as a source while the others act as receivers. Difficulties associated with possible lack of uniqueness will be discussed.

GJ-41 THE DIELECTRIC MEDIUM IN THE HYDROPHOBIC EFFECT. William H. Bishop*, Naval Medical Research Institute, Bethesda, Maryland 20814.

Two assumptions are frequently used in the biophysics of aqueous systems: (i) a dielectric mediates the interactions of polar molecules in aqueous phases and (ii) the dielectric constant of this medium is high and uniform up to molecular surfaces. Because of their great utility in rationalizing simple electrostatic effects in such polar systems, it is important to examine whether these assumptions also lead to deductions that are locally consistent with the hydrophobic effect. In this paper these macroscopic assumptions are applied to the microscopic non-linear integral equation for W(ik), the potential of mean force between two polar molecules. In systems of high dielectric constant, linearization of Boltzmann exponentials and approximation of three- molecule potentials of mean force by superposition of two-molecule potentials permit reduction to a linear integral equation for W(ik). It is shown that the microscopic electrostatic contributions to W(ik) exert an effect that is qualitatively similar to the screening effect of a macroscopic dielectric. It is further found that reducing the polarity of a molecule in a polar fluid shifts local pair probability density from energetically unfavorable to energetically favorable two-molecule configurations thereby promoting the hydrophobic effect. This effect furnishes the basic driving force in many biophysical processes.

GJ-43 NUMERICAL DOSIMETRIC ANALYSIS OF CHICK BRAIN EXPOSURE AT 50 AND 147 MHz: DO THE SCALED AMPLITUDE WINDOWS ALIGN? T. Whit Athey and Henry S. Ho. National Center for Devices and Radiological Health, Rockville, MD 20857.

A new numerical method for calculating the internal electromagnetic field distibution in arbitrarily shaped, inhomogeneous dielectric bodies has been applied to the dosimetric aspects of experiments on calcium efflux from chick brain preparations. This new method employs tetrahedra as the basic modeling units, allowing the model to fit curved surfaces much more closely than was possible with (cubic) block models. The chick brain is modeled as a slightly oblate spheroid at the bottom of an approximately hemispherical volume of buffer solution using 488 tetrahedral units. Dielectric properties with improved accuracy are used in the calculation. The present results are compared with several recent investigations, both experimental and theoretical, which have examined the possible alignment of amplitude windows found experimentally at 50 and 147 MHz.

GJ-45 SAR IN THE HEADS OF RATS EXPOSED TO 2450 MHz MICROWAVES UNDER VARIOUS EXPERIMENTAL CONDITIONS. Chung-Kwang Chou, Arthur W. Guy and John A. McDougall*. Bioelectromagnetics Research Laboratory, Depsrtment of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

Both positive and negative biological effects of microwaves and drug interactions are reported by several investigators exposing rats to 1 mW/cm^2 2450 MHz microwaves. There is a question whether these different results for the same incident power density reported could be a result of the rats being exposed differently. Exposure to far fields and near fields in anechoic chambers and guided waves in waveguides were performed. Since the reported drug interaction studies involved behavioral effects, it is important to determine whether the SAR in the head of the exposed animals were the same for the different reported studies. A twin well calorimetry system was used to measure the average SAR in the heads of exposed rats. Each rat carcus was stabilized for more than 8 hours to 30.5° C, followed by exposure in one of the exposure systems to high power density 2450 MHz microwaves for a short period. Immediately after exposure the animal was decapitsted snd the head was placed in the calorimeter for determination of SAR by inteɣration of the twin well termocouple voltage output for 4 hours. Local SARs at several locations in the brain were determined by measuring the rate of temperature rise with a Vitek 101 temperature probe.

GJ-47 MODELING MICROWAVE FIELD PATTERNS IN MAN WITH SURFACE WAVES. Albert W. Friend. Naval Electronics Systems Command, Washington, D.C. 20363, and Susan L. Gartner, Naval Medical Research Institute, Bethesda, MD 20814.

Microwave field patterns inside man are usually modeled using either extensive computer calculations or studied with phantoms. The microwave fields are not directly visualized, but must be inferred. We have previously shown that surface water waves in a wave tank can simulate microwave focusing effects in tissue. The wave patterns can be directly seen, and using the wave tank one can study standing waves, reflection, refraction, and interference, as well as focusing effects. The tissue in our previous work was modeled using a high density fluid, s-tetrabromoethane, immiscible with water, which modeled a high dielectric constant material. The fluid can be made to assume any shape by a glass plate submerged beneath it. The depth, surface tension, and viscosity of fluids can also be chosen to model differing dielectric properties and conductivities of tissues. Surface waves have one major limitation. They propagate on a two-dimensional surface, while microwaves propagate in three dimensions. Even so, surface waves can demonstrate in striking detail many of the phenomena that occur when microwaves interact with man and other biological objects. Their use is not limited to demonstrations, however. The experimental conditions in the wave tank can be altered so easily and the results directly observed, that the wave tank could become a useful additional tool. We discuss the techniques needed to use it successfully and some of the problems encountered.

GJ-49 SAR ANALYSIS BY INTERACTIVE COMPUTERIZED THERMOGRAPHY. Arthur W. Guy, Barry Neuhaus, and Chung Kwang Chou. Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

The Softa software package for the Oscar computerized AGA thermograph system was modified to allow interactive PDP 11 mini or micro computer analysis (RT11 or RSX11M operating system) of SAR distribution in exposed subjects from thermograph scans taken before and after RF exposure. The program converts raw thermograph data stored on standard magnetic tape to processed files of two dimensional images of the SAR distributions with a highlighted outline of the subject. Each image can be displayed in a gray scale format on a graphics terminal where any position on the image may be selected with a light pen for immediate display of the SAR and the temperature change resulting from the exposure. Also, both horizontal and vertical scans through the point showing SAR as a function of position may be displayed. Maximal, minimal, mean and standard deviation of the SAR along a single scan, a region of the image or the entire image may also be displayed. Hard copies may be made in the form of two dimensional gray scale, contour, and relief plots of the SAR distribution.

GJ-51 USE OF SURGICAL GLOVES TO MAKE REALISTIC MONKEY MODELS FOR RADIO-FREQUENCY (RF) AND MICROWAVE DOSIMETRIC MEASUREMENTS, Richard G. Olsen, John O. de Lorge, and W. Gregory Lotz, Bioenvironmental Sciences Department, Naval Aerospace Medical Research Laboratory, Pensacola, FL 32508

Common surgical gloves and a water-based, muscle-equivalent material were used to produce realistic models of rhesus (Macaca mulatta) and squirrel (Saimiri sciureus) monkeys for use in microwave and radio-frequency (RF) dosimetry. Previous models were typically encased in bulky foamed plastic molds. The so-called rubber-glove monkey models did not require a mold for support, and therefore the models could be placed in the same restraint devices as used by live animals during various microwave and RF irradiation experiments. The rubber-glove models, moreover, provide the facility of easily changing the relative positions of the limbs, in contrast to the fixed posture of foam-encased primate models. Dosimetric results were obtained in a variety of configurations using the rubber-glove model. Specific absorption rate (SAR) is given for the plane-wave irradiation of the rubber-glove models at 225 MHz, 1.29 GHz, and 5.6-5.8 GHz. Additional SAR data is give. for a rhesus monkey model inside a 275-MHz circular waveguide irradiation system where both the model and live rhesus subjects absorbed about one-third of the net input power. It is concluded that the rubber-glove monkey models are useful dosimetric tools where heat loss is not a critical factor or where those losses can be minimized.

GJ-53APPLICATION AND CONVERGENCE OF THE "SPECTRAL ITERATIVE TECHNIQUE" FOR THE CASE OF BIOLOGICAL BODIES AT 915 MHz., M. F. Sultan and R. Mittra, Electrical Engineering Department, University of Illinois, Urbana, IL 61801.

In this paper we describe the application of a recently developed method called the Spectral-Iterative Technique (SIT), to the problem of calculating the electromagnetic power deposition in the interior of a lossy, inhomogeneous biological medium. Emphasis has been placed on the intermediate or resonant frequency range which is difficult to handle using other numerical or asymptotic techniques. In its original form, the SIT technique was designed to solve problems involving perfectly conducting scatterers only. However, we show that with minor modifications the technique is readily adaptible to dielectric scattering problems as well. We have employed the SIT method to solve the problem of power deposition at 915 MHz in a wide range of configurations including two or more infinite, planar layers of fat and muscle media, cylindrical structures constituted of fat alone, muscle alone, or a combination of both. Power deposition has been successfully obtained in bodies with dimensions as large as 12 times the wavelength in muscle or fat. These types of problems cannot be adequately treated with conventional methods such as the method of moments, or the geometrical theory of diffraction. A study of the convergence of the SIT algorithm has shown that the convergence criteria involve the dielectric properties of the medium and the spacing between sampling points and that convergence can always be achieved with an appropriate choice of parameters.

GJ-55 HIGH INTENSITY SIXTY HZ ELECTRIC FIELD EXPOSURE FACILITY FOR NONHUMAN PRIMATES. William E. Cory, James J. Polonis*, and Walter R. Rogers. Division of Electronic Systems, Southwest Research Institute, San Antonio, TX 78284

Construction of a new Department of Energy facility at SwRI has been completed to allow use of baboons as surrogates for humans in studies of the behavioral and biological effects of electric fields. An insulated metal building houses 2 identical exposure areas separated by a Faraday shield. Each exposure area includes 6 individual and 1 group cage. The fiberglass cages rest on grounded metal grates. Stationary vertical fields are produced between the grates and bus bar anodes suspended from insulators. High voltage, 60 Hz, single phase transformers independently generate electric fields of up to 60 kV/m so that either portion of the facility can be the field or the sham exposure area. Optically coupled spherical dipole probes measure field strength; microcomputers operate feedback circuits to regulate field intensity and record exposure conditions. Instrumentation to automatically measure air temperature and humidity and the concentrations of ammonia and ozone is built into the building's heating and cooling system. The facility will be carefully mapped to document electric field homogeneity, harmonic content, corona, sound intensity, and grate vibration. Currently, we plan to perform a series of four experiments to examine behavioral, both operant and social, and neuroendocrine events associated with electric field exposure.

GJ-57 FOCUSED PHASED ARRAY HYPERTHERMIA APPLICATORS: A THEORETICAL AND EXPERIMENTAL STUDY. C. A. Cain, W. Gee, R. Magin, R. Mittra, and S. W. Lee. Department of Electrical Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801.

One approach to microwave hyperthermia applicator design for heating of superficial tumors is to use phased array antennas to rapidly scan a tumor with a minimal diameter beam or heating spot. Phased array technology is well established in radar and communication theory. However, phased arrays used for hyperthermia are different from conventional arrays in several important aspects. The focal point of hyperthermia arrays is in the near field only several cm away from the radiating aperture and the array must couple into a lossy medium of high dielectric constant instead of unbounded free space. Because of these differences, the design of hyperthermia arrays is not a trivial problem. The theory for design of an arbitrary array for near-field focusing is discussed along with experimental verification with a four-element linear array. This 2450 MHz array consists of four titanium dioxide loaded horn antennas immersed in deionized water and separated by 2.3 cm. The half-power bandwidth at the focal distance of 8.9 cm was 1.3 cm. A more reasonable candidate for an actual hyperthermia applicator, a nineteen element hexagonal planar array, will also be discussed.

GJ-59 ALTERING THERMAL DISTRIBUTION OF MICROWAVE HYPERTHERMIA APPLICATOR BY VARYING SALINITY OF BOLUS. Tilmer O. Engebretson, Jr., M.A*, Douglas R. Schumacher, B.S.* and John C. Blasko, M.D.* Swedish Hospital Tumor Institute, Seattle, WA 98104.

Local hyperthermia treatment utilizing the BSD-1000 microwave dual horn system may result in a heating pattern which is unsuitable for therapeutic heating of the superficial portions of tumors. To address this problem, the salinity of the water bolus, which acts as a coupling medium between the applicator and the patient, was varied. Increasing salinity causes a greater energy deposition in the solution and results in direct heating of the bolus bag. The effect is a modification of the heating pattern and an increase in utility for superficial heating. Results of these measurements will be presented as a practical method of modifying the heat distribution of the BSD-1000 dual horn system.

GJ-61 METHODS OF CONTROLLING AND MEASURING BRAINSTEM TEMPERATURE IN THE PRESENCE OF RADIOFREQUENCY FIELDS. Eleanor R. Adair and Robert O. Rawson*. John B. Pierce Foundation Laboratory, New Haven, CT 06519.

Pairs of sealed teflon tubes (1.1 mm I.D., 0.12 mm wall thickness) are implanted 2.5 mm apart under atereotaxic guidance in the medial preoptic/anterior hypothalamic area (PO/AH) of the squirrel monkey brain. During experiments to assess the thermoregulatory consequences of microwave exposure, one tube accepts a Vitek probe to measure PO/AH temperature. The other tube (a thermode) is perfused with temperature-controlled light silicone oil (Dow Corning L-45) via force-fit concentric tubes which emerge from a two-chambered Tygon circulator located above the monkey's head. The oil passes through the upper circulator chamber continuously, under light pressure, from a closed system which includes an oil reservoir, pump, coils immersed in hot (65 °C) and cold (10 °C) water baths, and a thermostatically-regulated mixing valve. Imposing a vacuum on the lower circulator chamber pulls the oil through the thermode, thereby altering tissue temperature near the thermode tip. Circulating oil temperatures of 50 or 20 °C raise or lower PO/AH temperature by 1.5 °C. Experiments using this preparation demonstrate that PO/AH heating augments, and cooling diminishes, both behavioral and autonomic thermoregulatory responses to microwave exposure. (Supported by USAF Contract F-33615-82-K-0600).

GJ-63 A BROADBAND IRRADIATION SYSTEM FOR THE SEARCH OF LOW-INTENSITY MM-WAVE BIOEFFECTS. F. Kremer, L. Santo, W. Rauscher. Max-Planck-Institut für Festkörperforschung. Heisenbergstr. 1, 7000 Stuttgart 80. Federal Republic of Germany.

An irradiation system is described which fulfills the special biological and physical requirements for studies of bioeffects of low-intensity mm-wave radiation: 1) The whole irradiation system includes two electromagnetically isolated chambers, one for irradiation, one for control. 2) The sample container (a fused silica plate, 1 mm thickness and 50 mm radius with an indented circle of 40 mm radius and a depth of 0.3 + 0.02 mm) can easily be sterilized. 3) The sample temperature, controlled with an accuracy of $\pm 0.1^{\circ}C$, is adjustable over a wide range. 4) The cells can be supplied with oxygen via a semipermeable membrane which covers the sample container. 5) Due to a very good thermal coupling of the sample container with a heat bath the microwave induced temperature increase is less than $0.3^{\circ}C$ at a power density of 5 mW/cm^2. 6) The whole irradiation system is broadband over the frequency range from 40 GHz to 110 GHz. 7) The sample thickness (i.e. the depth of the indentation in the sample container)is approximately of the same size as the penetration depth of the mm-wave radiation. 8) The ratio of the irradiated sample volume to the total sample volume (ca. 400 µl) is nearly 1.

GJ-65 EFFECT OF PULSED 27.12 MHZ ON CHRONIC WOUNDS IN THE ELDERLY. Richard H. C. Bentall and Raonaid M. Cobban*. Institute of Bioelectrical Research, Romanno Bridge, West Linton, Peeblesshire, Scotland.

There are a number of chronic wounds that occur more frequently in the elderly age group, such as decubitus skin ulcers and leg ulcers. A pilot study was started to ascertain the alteration in the rate of healing in these groups of ulcers using a locally applied device with a 100 μ/sec pulse and 1 KHz repetition rate and average total output of less than 10 μ/W. In double-blind clinical groupings, measurements of healing rate were made using photographic, planimetric, volumetric and infrared techniques to assess the alteration in healing rate. The initial results show that there is a significant rate change in healing of those chronic wounds receiving the active device. This beneficial rate change may in the future have therapeutic value in clinical use.

SESSION H Genetic/Developmental Effects

Cochairs: **Friedrick Kremer and Jerome H. Krupp**

H-1 DNA REPLICATION IN SPLEEN AND BONE MARROW OF MICE OURING RFR EXPOSURE. Roger F. Brown[1] and Stanley V. Marshall[2]. [1]Life Sciences Department, University of Missouri-Rolla, Rolla, MO 65401 and [2]Southwest Research Institute, San Antonio, TX 78284.

This study was conducted to determine if exposure to continuous wave RFR perturbs ONA replication in the intact animal. RFR exposures (E polarization) were at 400 MHz, 800 MHz, and 1200 MHz. Field strengths were adjusted to give an SAR of 4 W/kg at each of the three test frequencies. ONA replication was monitored by a dual labeling procedure with each animal receiving an iv injection of [^{14}C]thymidine (0.2 ml; 2.5 µCi/ml) followed 90 min later by iv administration of [^{3}H]thymidine (0.2 ml; 50 µCi/ml). Immediately after the second injection, the animals were subjected to a 20-min RFR (or sham) exposure and then sacrificed. Acid-insoluble radioactivities in the nuclear fraction of the spleen and bone marrow samples removed from the animals were assayed with final results expressed as [^{3}H]/[^{14}C] ratios. Tissue samples from a separate group of mice treated with the inhibitor hydroxyurea shortly before injection of [^{3}H]thymidine exhibited [^{3}H]/[^{14}C] ratios 30-fold lower than the untreated controls. In contrast, the [^{3}H]/[^{14}C] ratios for tissues from mice exposed to 400 MHz, 800 MHz, or 1200 MHz fields were found to be the same as those of their sham-exposed controls indicating no RFR perturbation of on-going DNA replication. (Supported by USAF Contract No. 33615 80 C 0613).

H-2 THE NON-THERMAL INFLUENCE OF MILLIMETER WAVE RADIATION ON THE PUFFING OF GIANT CHROMOSOMES. *F. Kremer, Chr. Koschnitzke, L. Santo, P. Quick, A. Poglitsch.* Max-Planck-Institut f. Festkörperforschung, Heisenbergstr. 1, 7000 Stuttgart 80 and Institut für Allgemeine Genetik, Universität Hohenheim, Garbenstr. 30, 7000 Stuttgart 70, Federal Republic of Germany.

A non-thermal influence of millimeter wave radiation (swept from 64 GHz to 69 GHz and also at single stabilized frequencies, power density ≤ 5 mW/cm^2) on the activity of a certain gene locus in giant chromosomes of salivary glands of larvae of the midge *Acricotopus lucidus* is discovered. The effect is cytologically manifested directly at the chromosome level, as established by experiments carried out blind, to a level of significance $P < 0.005$. In studying the puffing pattern of the giant chromosomes it was found, that the Balbisniring BR2 in the chromosome II exhibits reductions after irradiation with millimeter waves. Concerning the very low photon energy of mm-waves compared to the thermal energy kT one has to conclude that the coherence of the applied radiation must be decisive for the observed effect. The results could possibly be understood by H. Fröhlich's theory of coherent electric excitations in biological systems.

H-3 EFFECTS OF 0.915 and 9.4 GHz CW MICROWAVES ON MEIOSIS IN MALE MICE. Ewa Manikowska-Czerska,* Przemyslaw Czerski, and William M. Leach.* National Center for Devices and Radiological Health, Food and Drug Administration, U. S. Public Health Service, Rockville, MD 20857.

Appearance of chromosomal translocations in meiotic cells of male mice has been reported after exposure to 9.4 pulsed and 2.45 GHz CW microwaves. In order to extend these observations, male ICR mice were exposed 30 minutes daily, six days a week for two weeks with 0.915 and 9.4 GHz CW microwaves in a waveguide and in an anechoic chamber, respectively, at whole body average absorbed dose rates of 1 and 20 mW/g. Two days after termination of exposure, cells were removed from the testes and prepared for light microscopic examination. The numbers of cells in spermatagonial, and in metaphase I and metaphase II of meiotic stages of maturation were determined. The number and structure of chromosomes were also determined in the metaphase stages. In comparison with sham-exposed controls, the number of metaphases decreased at 1 mW/g, but appeared unaffected at 20 mW/g in 0.915 GHz exposed mice. At 9.4 GHz, the number of metaphases increased at both dose rates in comparison with controls. Translocations were observed at both frequencies and at both dose rates. The results are discussed in relation to similar changes reported previously after 2.45 GHz (Manikowska-Czerska et. al, 4th Annual Conference, this Society. 1982, p.85 in the Book of Abstracts) and pulsed 9.4 GHz (Manikowska et. al, Experientia 35:388-390, 1979).

H-4 DOMINANT LETHAL TESTING AFTER EXPOSURE OF MICE TO 0.915 GHz MICROWAVES. Ewa Manikowska-Czerska,* Przemyslaw Czerski, and William M. Leach.* National Center for Devices and Radiological Health, Food and Drug Administration, U. S. Public Health Service, Rockville, MD 20857.

In order to determine whether the chromosomal damage that is induced in testes of mice by microwave exposure may be heritable, dominant lethal testing was performed with ICR mice. Males were exposed 30 minutes daily, six days a week for two weeks to 0.915 GHz CW microwaves in a waveguide at average absorbed dose rates of 1 and 20 mW/g. Sham-exposed animals served as controls. Each group was 15 males. Three weeks after the end of exposure, males were mated with unexposed females. The females were terminated at day 13-14 of gestation, and the numbers of live and dead implants were determined. Karyotypic analysis was performed on livers from 50 fetuses exposed at 1 mW/g and 49 fetuses exposed at 20 mW/g. The post-implantation loss, about 20 percent in both the 1 and 20 mW/g exposed groups, was significantly more than the 4.9 percent loss in the sham group. Liver cells from two fetuses, one from each of the exposed groups, contained chromosomal translocations between two large chromosomes. The test results are in essential agreement with results reported by others with the dominant lethal test after exposure to 2.45 and 1.7 GHz microwaves. Furthermore, the appearance of translocations in offspring confirms the existence of chromosome damage detected by direct examination in meiotic cells (reported elsewhere at this meeting).

H-5 QUANTITATION OF SYNAPSES IN THE CEREBELLA OF NEWBORN RATS EXPOSED TO 2450 MHz MICROWAVE IRRADIATION. Ernest Albert, Mahmoud Sherif*, Gilda Kornhauser, Gary Cohen and Jack Monahan**. Department of Anatomy, George Washington University Medical Center, Washington, D.C. 20037 and *School of Medicine, Kuwait University and **Division of Risk Assessment, National Center for Devices and Radiological Health, FDA, Rockville, Maryland.

Six 1 day-old rat pups were irradiated or sham exposed to 2450 MHz (CW) at 5 mW/cm^2 for seven hours/day for ten consecutive days. On the eleventh day the brains of three control and three experimental animals were fixed with glutaraldehyde by cardiac perfusion and prepared for electron microscopy. Matching areas of the cerebellar anterior lobe were thin-sectioned and the molecular layer randomly photographed at 3000X magnification with a Jeol 100B electron microscope. Each photograph was of an area in the cerebellum of approx. 6600 um^2. Synapses in the molecular layer were identified only if they possessed a synaptic cleft, membrane density and vesicles. In the three control rats the synapses (± S.E.) averaged 51.75 ± 6.97 (animal #1 = 45.11 ± 5.60, animal #2 = 54.11 ± 4.54 and animal #3 = 59.00 ± 4.22). In experimental rats the synapses averaged 82.30 ±6.11 (animal #1 = 78.18 ±4.45, animal #2 = 74.62 ±4.26 and animal #3, 94.10 ± 11.1). These differences are statistically significant ($p<0.001$). Total area examined in controls was 2.9×10^5 um^2 and in experimentals 2.3×10^5 um^2.

H-6 DEVELOPMENTAL RESPONSE OF SEA URCHIN EMBRYOS TO 915 AND 147 MHz NONIONIZING RADIATION. Ernest Albert, Frank Slaby, Kurt Johnson and Norio Nakatsuji. Department of Anatomy, George Washington University Medical Center, Washington, D.C. 20037.

Strongylocantrotus purpuratus eggs were fertilized and placed in two Crawford cells housed in an incubator maintained at 14 ± 0.2°C. Embryos in one cell were exposed to irradiation at either 915 MHz (1 mW/cm^2) or 147 MHz (amplitude modulated at 16 Hz) at a power density of .75 mW/cm^2. Embryos in the other cell were sham irradiated. At the end of each irradiation period, the embryos were fixed in glutaraldehyde, placed on glass slides and randomly chosen fields photographed. Photographs were then examined to see if there were developmental differences between irradiated and sham irradiated embryos. There appeared to be no developmental differences between experimental and control embryos up to 48 hrs of irradiation, e.g. at 25 hrs both groups were mesenchyme blastulae and at 39 hrs they were early gastrulae. Only embryos exposed to 915 MHz were examined at 62 hrs after irradiation. At this time both irradiated and control embryos had reached the early prism stage with numerous spicules. Preliminary observations suggest that there may be a slight retardation in the development of the 62 hrs irradiated embryos. The sham irradiated embryos appeared to have more well developed spicules and were more prism shaped than the irradiated embryos.

H-7 LACK OF EMBRYOTOXIC EFFECTS FROM NONTHERMAL EXPOSURE OF RATS TO 100 MHz RADIOFREQUENCY RADIATION. Joseph M. Lary*, David L. Conover*, and Peggy H. Johnson*. Division of Biomedical and Behavioral Science, National Institute for Occupational Safety and Health, Cincinnati, OH 45226.

This study was conducted to determine if exposure to radiofrequency (RF) radiation at the limits of the 1982 ANSI C95.1 RF/microwave exposure standard is teratogenic or embryotoxic in rats. The 1982 ANSI standard is based on an average whole body specific absorption rate (SAR) limit of 0.4 W/kg. We exposed 34 pregnant Sprague-Dawley rats in a TEM cell to a 100 MHz RF field at a power density of 25 mW/cm^2. Rats were exposed 6 hours 40 minutes daily on gestation days 6-11. The exposure resulted in an average SAR of 0.4 W/kg and caused no increase in maternal colonic temperature. Another 32 pregnant rats were sham-irradiated at 0 mW/cm^2 for the same period to serve as controls. All rats were sacrificed on gestation day 20 for teratological examination. Irradiated rats did not differ from sham-irradiated rats with respect to the number of implantations per litter, percentage of implantations dead or resorbed, percentage of fetuses malformed, fetal weight, fetal crown-rump length, or fetal sex ratio. Irradiated fetuses had fewer minor skeletal variations than controls. The results indicate that RF radiation exposure at the limits of the 1982 ANSI standard is not teratogenic or embryotoxic in the rat.

H-8 GROWTH AND DEVELOPMENT OF RHESUS MONKEYS CHRONICALLY EXPOSED TO ELF ELECTRIC AND MAGNETIC FIELDS. W. Gregory Lotz and James D. Grissett. Bioenvironmental Sciences Department, Naval Aerospace Medical Research Laboratory, Pensacola, FL 32508

Sixty rhesus monkeys (Macaca mulatta), 34 males and 26 females, are being studied to evaluate growth and development effects of the low level electric and magnetic fields associated with the Navy's extremely low frequency (ELF) communications system. The current project uses the same field parameters (0.2 mT and 20 V/m) as a previous study in which an enhanced growth rate occurred in pubescent male rhesus monkeys. In the present study, the monkeys entered the project at one month of age and are now approximately 3.5 years old. One-half of the animals are exposed 22 hr/day while the other half serve as controls. The biological endpoints being studied include body weight, bone growth, steroid hormones (testosterone, dihydrotestosterone, estradiol, and progesterone), hematology, and menstrual cycle data. No differences between exposed and control groups were observed prior to puberty for any endpoint studied. Data for pubescent animals are now being collected and evaluated with emphasis on physical growth parameters and their endocrine correlates, including those that mark the onset of puberty and the cycling of sex hormone levels.

H-9 BEHAVIORAL AND DEVELOPMENTAL EVALUATION OF RATS EXPOSED IN UTERO TO MICROWAVE FIELDS. Mary Ellen O'Connor, David A. Bartsch*, James Chrobak*, John C. Proksa*, and Monica Indart*. University of Tulsa, Tulsa, Oklahoma 74104

Laboratory bred, primagravid Long-Evans rats were placed in individual plexiglas holders and exposed in an environmentally controlled anechoic chamber to 2450-MHz CW microwave radiation at an average power density of 30 mW/cm^2 for 6 hours daily throughout the first 19 days of gestation. Passive cage control and holder control groups were also maintained for purposes of statistical comparison. Twelve of the females delivered litters with seven or more pups and these litters were culled to seven pups each. Offspring were examined regularly for several aspects of behavioral and nervous system development. Indices included: body mass, righting, eye opening, visual cliff, inclined plane, open field, avoidance, and positioning and movement in a heated runway. A multivariate analysis on the developmental measures did not indicate that exposed animals were distinguishable from cage control subjects. However, the holder group was significantly different from the other groups. In the behavioral tests, the subjects did not show differences in avoidance learning. However, exposed animals when placed in a runway heated to form a gradient from 17° to 38° C spent more time in the cooler sections of the runway. Thus, the exposed animals evidenced postnatal sensitization only with regard to thermal stimuli.

H-10 EMW AS AN EMBRYOTOXIC AGENT. Hane Pafková, Institute of Hygiene & Epidemiology, Prague, Czechoslovakia

The article eccentuates the importance to solve the problem of possible embryotoxic effects of electromagnetic waves (EMW), when artificial EMW are inseparebleper t of life environment. Present state of knowing is summarised with underlining of gradual phases and tendency of research. The influence of externel fector on the different morfogenetic systems, which operete not only in prenatal period, but throughout the whole life of an individual, will be disscused. The need to base the objective appreciation of environmentel fields embryotoxicity elso upon the functionel disturbances, occuring till in postnetal period of life, is emphesized.

H-11 THE EFFECTS OF PULSED ELECTROMAGNETIC FIELDS (PEMF) ON CHICK EMBRYOS AFTER LIMB AMPUTATION. Betty F. Sisken, Ira Fowler* and Richard Kryscio*, Wenner-Gren Research Lab, Dept. of Anatomy, Dept. of Statistics, Univ. of Kentucky, Lexington, KY 40506

We have data on a large sample of chick embryos that have been treated with two different PEMF signals demonstrating no significant effects on normal development. We have also investigated the effects of such signals on the induction of limb regeneration in amputated limbs of chick embryos. The right forelimb of 217 chick embryos (4 days of age) were amputated. Seventy-eight of these embryos were subsequently incubated in a conventional egg incubator and were designated as "controls". Four different PEMF signals were used on the remaining 139 embryos. In no group, control or treated, did we observe any induction of regeneration. However, using a chi square statistical test, we did see a significant (0.05→.001) increase in the incidence of body abnormalities, 6 days post-surgery, that was correlated directly with the total number of hours of exposure to any of the signals. The one exception was found in a group where the exposure to PEMF was delayed for the first 24 hours after surgery. We conclude from these studies that PEMF does not induce limb regeneration in our chick model, but that it does interfere with normal processes of development when combined with surgical procedures such ar limb amputation. Supported by the Veteran's Administration Research Program.

H-12 THE EFFECTS OF PULSED ELECTROMAGNETIC FIELDS(PEMF) ON NORMAL CHICK DEVELOPMENT Betty F. Sisken, Ira Fowler*, Chris Mayaud* and Richard Kryscio*, Wenner Gren Research Lab., Dept. of Anatomy & Dept. of Statistics, University of Kentucky, Lexington, KY 40506, and Dept. Orthopaedic Surgery, Mt. Sinai Sch. Medicine, NY, NY 10028

A number of recent studies, using a comparatively small sample size, have reported on the effects of clinical-type PEMF signals on normal chick development. Our studies evaluated 1008 embryos. Two different pulse signals from research units provided by Electrobiology, Inc. were examined. Fertile eggs were exposed to these signals at 37°C either continuously for 7 days or for the first 24 hours only. Control eggs were placed in a different incubator, at 37°C, far removed from the coils. All embryos were collected after 7 days of incubation, fixed in formalin, coded and scored at a later time. Scoring was done in a doubls-blind fashion, and the data was analyzed using a chi square statistical test to determine the frequency of abnormalities. In 78 eggs treated with one signal in either a horizontal or vertical position, no significant differences were noted relative to the 73 matched control eggs. In 376 eggs treated with the second signal, no significant incidence of abnormality was found relative to 273 matched controls. A separate group of eggs were treated or untreated at 39°C to test the effects of PEMF with increased temperature. A significant increase in morphological abnormalities occurred in 84 treated relative to the 106 controls. Supported in part by the Veteran's Administration Research Program.

SESSION I Dielectric Properties/Dosimetry

Cochairs: Everett C. Burdette and Kenneth R. Foster

I-1 AN ANALYSIS OF THE ROLE OF COOPERATIVE EFFECTS IN EXPLAINING THE COUPLING OF WEAK ELECTRIC FIELDS TO BIOLOGIC MEMBRANES. James D. Bond, Carol A. Jordan, and Silverio P. Almeido, Science Applications, Inc., McLean, VA 22102

We have developed a conventional lattice statistics formulation to examine the possibility of cooperative interactions among membrane subunits as being the vehicle by which a biological membrane responds to a weak, external electric field. The field is assumed to precipitate the cooperative reaponse. An analytic expression for this field in terms of subunit interaction parameters is presented, and a comparison is made between the magnitude of parameter values and well characterized intrinsic interaction energies within membrane systems. The Bragg-Williams approximation is employed in our analysia.

I-2 DIELECTRIC MEASUREMENTS OF SOLID TUMORS THROUGH THE INTACT SKIN. Everette C. Burdette and Michael L. Studwell*. Biomedical Research Division, Georgia Institute of Technology, Atlanta, CA 30332

A technique was devised for experimentally determining the dielectric characteristics of subcutaneous tumors and normal tissues noninvasively through the intact skin. A coaxial waveguide operating in the TEM mode was used to interrogate normal tissues and solid tumors at multiple frequencies first directly and then noninvasively through the intact skin. The measured complex impedance data and known material dielectric property information at different frequencies were used in a numerical model to determine the dielectric characteristics of subcutaneous solid tumors in rats and humans. Measurements were performed over the 3-1000 MHz frequency range. Syngeneic methylocholanthrene-induced sarcoma and normal muscle, brain, and skin were examined in 10 rats. Human breast carcinoma and normal breast were measured in 5 patients. Dielectric constant differences between direct measurements of tumor and normal muscle were significant over the 3-60 MHz frequency range. Results from noninvasive measurements differed in absolute values from the direct measurements, but relative dielectric differences were maintained. The relative differences in conductivity of muscle and tumor were the same for both invasive and noninvasive measurements. Overall agreement between noninvasive and direct tissue measurements was well within the muscle/tumor differences. Relative differences between tumor and normal human breast tissue measured noninvasively were smaller than for direct tissue measurements. (Supported by NCI Grant No. CA22771.)

I-3 DIELECTRIC ABSORPTION OF BOUND WATER AND ITS RELATION TO OTHER TRANSPORT PROPERTIES OF POLYMER SOLUTIONS. Erik Cheever*, Kenneth R. Foster, Jonathan B. Leonard*, and Frank D. Blum*. Departments of Bioengineering, University of Pennsylvania and Chemistry, Drexel University, Philadelphia, PA 19104.

Biological materials exhibit dielectric absorption at low GHz frequencies that is attributed in part to dielectric relaxation of the water associated with the macromolecules. It has often been suggested that other transport properties in these systems should also be affected by the presence of hydration water. However, the great complexity of biological systems makes the analysis of these effects quite difficult. We have studied a variety of transport phenomena in simple model systems, consisting of concentrated aqueous solutions of the hydrophilic polymers poly(ethylene oxide) and poly(vinyl alcohol). These solutions have dielectric properties at UHF-microwave frequencies that resemble those of biopolymer solutions of similar water content (Kaatze, Prog. Colloid Sci. Polymer Sci. Supp., 65,214 (1978)). We have in addition measured the self diffusion coefficient of water, the electrical conductivity in the presence of added electrolyte, and the thermal conductivity. All of these data can be analyzed using the same mixture theory, but show significant effects due to the presence of the hydration water. It appears simply that the viscosity of the hydration water is an order of magnitude larger than that of the bulk liquid. The present observations should help resolve controversies in the interpretation of transport data from biological systems and the physical properties of "biological water".

I-4 THE DIELECTRIC PROPERTIES OF PLANT STEMS. Francis X. Hart. Department of Physics, The University of the South, Sewanee, TN 37375

The dielectric spectrum (capacitance and conductance vs. frequency) of a plant stem can be conveniently measured in-vivo by time domain dielectric spectroscopy. In this technique a voltage step is applied to a stem. The resulting current-time characteristic is sampled by a microprocessor and Fourier transformed to yield the dielectric spectrum. Spectra were obtained for seven electrode separations along a Poinsettia stem. The inverse capacitance and conductance were plotted vs. separation for 50 frequencies from .35 to 350 Hz. Least square fits yielded the effective dielectric constant and conductivity of the stem itself over this frequency range. A log-log plot of these parameters vs. frequency shows a two-stage linear decrease of the dielectric constant from 10^8 to 2×10^6 and a simple DC conductivity of 0.1 S/m. These results are compared to those for fast-ion-conductors using the Universal Dielectric Response model.

I-5 *BODY IMPEDANCE FOR CONTACT ELECTRIC HAZARD IN THE VLF TO MF BAND.* Hiroshi Kanai*, Indira Chatterjee*, and Om P. Gandhi. Department of Electrical Engineering, University of Utah, Salt Lake City, UT 84112

A knowledge of the body impedance between a finger and the feet is essential in the analysis of electric hazard to humans in contact with metallic objects in 10 kHz to 10 MHz fields. The purpose of our measurements was to determine the body impedance of some human subjects in this frequency range, to analyze the frequency characteristics and to obtain a simple equivalent circuit of the body impedance. The body impedances of seven subjects were measured in the frequency range 0.5 kHz to 50 MHz. The measured impedance includes electrode impedance between the electrode and skin, spread impedance near the electrode, body impedance, stray capacitance between the body surface and ground and inductance due to the grounding lead wire. These components were separated and the body impedance was obtained and represented by a simple equivalent circuit. This circuit consists of a resistance due to extracellular fluid, in parallel with an impedance due to low-frequency muscle relaxation (time constant = 4 μs) and an impedance due to high frequency blood relaxation (time constant = 6 μs). At frequencies higher than 20 MHz, the body impedance shows a resonance due to the electrical properties of the body and inductance of grounding wire. These results and their importance in VLF to MF hazard threshold analysis will be presented.

I-6 SIXTY-HERTZ IMPEDANCE BETWEEN RATS AND GROUND. William T. Kaune, Michael C. Miller* and D. Ian Hilton. Pacific Northwest Laboratory, Richland, WA 99352

Many experiments investigating the biological effects of 60-Hz electric fields have grounded both the experimental subjects and their watering systems to avoid spark discharges. To evaluate the effectiveness of this approach for the most commonly used laboratory animal, we measured the 60-Hz impedance, Z_g, between 29 male rats and ground. Each rat was tested by passing a known 0.7-1.0 μA current through Z_g and measuring the voltage across it every 10 s for 20 hrs. The rat was not restrained. A histogram of log (Z_g) for all animals was approximately normal with a geometrical mean and standard deviation of 204 kΩ and 4.2, respectively. Approximately 15% of the measured impedances were greater than 1 megΩ and almost 1% were greater than 10 megΩ. This means that a rat standing on ground can not always be considered to be electrically grounded. Induced body voltages will exceed 70 V about 1% of the time when the exposure field is 50 kV/m. Also, essentially all of a rat's short-circuit current (e.g., ~7 μA at 50 kV/m) will pass through its mouth when drinking from a grounded nozzle. This current may be perceptible.

I-7 RELAXATION PROCESSES ON A PICOSECOND TIME SCALE IN HAEMOGLOBIN AND POLY-L-ALANINE OBSERVED BY MM-WAVE-SPECTROSCOPY. F. Kremer, L. Genzel, A. Poglitsch, G. Bechtold. Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 7000 Stuttgart 80, Federal Republic of Germany.

Broadband measurements of the millimeter wave and far-infrared absorption (10 GHz - 10^4 GHz) of lyophilized haemoglobin are reported. Additionally, the absorption of poly-L-alanine and crystalline L-alanine at 70 GHz was measured for comparison. All measurements were extended from liquid helium to room temperature. For the millimeter range this was attained by using the novel untuned cavity technique. It was found that the millimeter wave absorption of the materials increased nearly exponentially with temperature and increased as $\nu^{1.5}$ - ν^2 with frequency. The far-infrared absorption of haemoglobin showed broad bands with almost no temperature dependence. The frequency- und temperature dependence of the millimeter wave absorption is quantitatively described as due to three distinct relaxation processes on a picosecond timescale occuring in asymmetric double well potentials. These processes are most probably assigned to the NH...OC hydrogen bonds of the peptide backbone.

I-8 DIELECTRIC STUDIES OF SICKLE CELL HEMOGLOBIN (Hb S). Z.Delalic, S. Chang and S. Takashima, Department of Bioengineering, University of Pennsylvania K. Adachi and T.Asakura, Children's Hospital. Philadelphia, PA 19104.

Sickle cell hemoglobin (Hb S) forms liquid crystalline tactoids when they are deoxygenated. Tactoids (or gels) are filamentous polymers of Hb S molecules which are stabilized mainly by hydrophobic bonds. The internal structure of gels is similar to that of crystalline state. The transition from solution state to gel state has been investigated using NMR, viscosity and light scattering. Using dielectric constant measurement techniques, we have been studying the kinetics of gelation of Hb S. The dielectric constant of Hb S decreases considerably upon gelation because of the interlocking of each molecule in the lattice of gels. In the course of these experiments, we found that the dielectric properties of Hb S gels are easily affected by the input RF fields which are used for dielectric measurements. This non-linear dielectric properties of gels may be due to the perturbation of gel structure by RF fields. The critical field strength for the onset of non-linearity depends on the concentration of Hb S and also on the temperature of samples. This finding led us to cellular level studies in which RF pulsed fields were used to reverse the sickling of S.S. erythrocytes.

This work is supported by ONR N00014-82-K-0321. T.A. and K.A. are supported by NIH HL-20750 and HL-18226.

I-9 ELECTROMAGNETIC FIELD MEASUREMENTS AND PRELIMINARY DOSIMETRY FOR THE US-USSR COOPERATIVE AGREEMENT Howard Bassen*, V. Varetski**, V. Djachenko**
*National Center for Devices and Radiological Health, Rockville,MD. 20857, USA.
**Marzeev Institute of Communal and General Hygiene Kiev, USSR.

Measurements of electric field distribution in the exposure chamber of the Marzeev Research Institute, Kiev included E-field spatial distribution and polarization, scattering by cages and rats, absolute calibration of equivalent power density (E^2), and Specific Absorption Rate in rat phantoms and cadavers. Fields were mapped in the 1 square meter exposure zone. The spatial uniformity and polarization consistency were checked by the use of miniature E-field probes containing 3 orthogonal dipoles The USSR power density calibration was within 0.5dB of the U.S. calibration. The electric field strengths (E^2) were found to closely approximate a far-field, uniform exposure. The polarization of the fields was constant and scattering was minimal ($\pm$10%) with rats placed in each cage. Standing waves with $\pm$ 25% variations were observed when about 1 ml of water was spilled on the floor of a cage to simulate urine. Dosimetric data were obtained using a microwave isotropic implantable miniature E-field probe. Field values (E^2) in the head and abdomen of a rat phantom composed of microwave simulated-muscle tissue were measured. Preliminary data taken in a rat phantom revealed a resonant peak in the center of the head. Data was also taken at this site with saline filled electrodes attached to the phantom head. Comparisons were also made with data obtained in rat cadavers.

I-10 FAST-FOURIER-TRANSFORM METHOD FOR CALCULATION OF SAR DISTRIBUTIONS IN FINELY-DISCRETIZED INHOMOGENEOUS MODELS OF BIOLOGICAL BODIES. David T. Borup* and Om P. Gandhi. Department of Electrical Engineering, University of Utah, Salt Lake City, UT 84112

A novel iterative approach for calculations of SAR distributiona in arbitrary lossy, dielectric bodiea will be described. To date, the method has been used for 2-D problems where its accuracy has been confirmed by comparison with the analytic solutiona for homogeneous and layered circular cylindrical bodies. With computation timea that are proportional to $N \log_2 N$ rather than N^2 to N^3 for the method of moments, the preaent approach should be extendable to 3-D bodiea with $N = 10^4$ to 10^5 cells allowing thereby details of SAR distributions that are needed for EM hyperthermia as well as for assessing biological effects.

I-11 QUANTIFICATION OF ELECTROMAGNETIC ABSORPTION IN HUMANS FROM BODY-MOUNTED COMMUNICATION TRANSRECEIVERS. Indira Chatterjee*, Yong-Gong Gu*, and Om P. Gandhi. Department of Electrical Engineering, University of Utah, Salt Lake City, UT 84112

The internal electric (E) field in a full-size adult male mannikin (height = 1.82 m) due to exposure to 1.5 watt body-mounted communication transreceivers, at frequencies 50, 150, 450, and 800 MHz, has been measured for various locations of the antenna vis-a-vis the body. The mannikin was filled with two-thirds muscle-simulant biological phantom mixtures at each of the frequencies. The complex permittivities (ε^*) were confirmed by measurement of the attenuation and phase constants of the damped wave in a coaxial slotted line filled with these mixtures. The three-dimensional implantable probes used for internal E measurement were the BRH model 15 for 450 and 800 MHz, and that made by Holaday Industries for 50 and 150 MHz. The paper will give the distribution of SAR and internal E^2 at various positions in the body. Relatively superficial depositions at points closer to the location of the antenna were obtained for the two higher frequencies with SAR's typically less than 1-2 W/kg. Considerably reduced SAR's were obtained at the two lower frequencies, on account of in-depth and wider dissemination of the absorbed energy and the relatively high ε^* which results in an increased shielding of the body.

I-12 FURTHER STUDIES OF POWER DEPOSITION IN HEAD MODELS EXPOSED TO HAND-HELD TRANSCEIVERS AND TELEPHONES. Robert F. Cleveland, Federal Communications Commission, Office of Science and Technology, Washington, D.C. 20554, T. Whit Athey, National Center for Devices and Radiological Health, Division of Electronic Products Rockville, MD 20857

We previously reported the results of preliminary studies in which a head model consisting of a human skull and tissue-equivalent phantom materials was exposed to emissions from 1.5 watt hand-held transceivers transmitting at 806-821 MHz. We have now extended these studies using more realistic modeling techniques, and we have also examined the effects of other hand-held RF devices including portable telephones. The electric fields inside the model were measured with an isotropic implantable E-field probe. Various transceiver orientations and probe scans were tested as before. Internal E-fields appear to be generally highest in near-surface regions closest to antenna feed-points and fall off rapidly with increasing depth into the model. The implications of these results with respect to safety standards will be discussed.

SESSION J Poster Papers II

***Chair:* Howard Wachtel**

GJ-2 EFFECTS OF MICROWAVE RADIATION PRE- AND PERINATALLY ON NEUROBEHAVIORAL FUNCTIONING IN RATS. C. L. Mitchell, M. J. Galvin, H. A. Tilson*, O. I. McRee. National Institute of Environmental Health Sciences, Research Triangle Park, NC 27709

Rats exposed to microwaves (2450 MHz, 10mW/cm^2, 3 hrs/day) prenatally (days 5 through 20 of gestation) and perinatally (same as above plus days 2 through 20 postnatally) were examined in a neurobehavioral test battery on days 30 and 100 postnatally (first study). Phenomena measured were body weight, locomotor activity, startle to acoustic and air puff stimuli, fore-/hindlimb grip strength, negative geotaxis, reaction to heat stimulus, and swim time to exhaustion. The pre- and perinatally exposed rats (male and female) were heavier at both 30 and 100 days of age than their appropriate controls. The perinatally exposed animals had a shorter swim time to exhaustion at 30, but not 100, days of age relative to sham exposed rats. No other consistent effects were observed. In a second experiment, rats treated as described above were examined for alterations in body weight, locomotor activity, air puff stimuli, reaction to heat stimulus, and swim time to exhaustion at days 30-36 postnatal. Again, pre- and perinatally microwave exposed rats were heavier than sham exposed rats. Also, both groups of microwave exposed rats had a shorter swim time than sham exposed rats. These data suggest that endurance tests may be useful in demonstrating subtle behavioral effects resulting from microwave exposure during the pre- and perinatal period.

GJ-4 BEHAVORIAL METHODS FOR ASSESSING CNS FUNCTION FOLLOWING MICROWAVE EXPOSURE. John C. Monahan, National Center for Devices and Radiological Health, Office of Radiological Health, Division of Risk Assessment.

At the present time efforts are underway, both in the U.S. and the Soviet Union to develop test methods for use in duplicate experiments. The primary objective of these initial studies is to determine the most sensitive approaches for evaluating microwave effects on the functional state of the central nervous system. The methods selected will subsequently be used in long-term studies in both countries for investigating the effects of low-level exposure.

Fisher 344 male rats approximately 250 gms were adapted in an anechoic chamber for 8 days prior to exposure. On day 9 subjects were exposed to 2450 MHz, CW radiation, 0 or 10 mW/cm^2 for 7 hours. During the adaption period all subjects were given 3 trials to determine their latency to move from a lighted to a darkened chamber. Only those animals which exhibited this behavior were used. On the last day of adaption, subjects received foot shock following entry into the darkened chamber. Immediately following microwave exposure subjects were evaluated both for open field behavior and entry to the darkened chamber. Details of the animal selection criteria, exposure conditions and initial results obtained on these behavioral measures will be presented.

GJ-6 EVOKED POTENTIALS AND SUBJECTIVE RESPONSES OF MEN UNDER INDUCED AND DIURNAL ELEVATIONS OF TEMPERATURE. D.L. Reeves* and E.L. Wike.* Univ. of KS, Lawrence, KS 66045; D.R. Justesen, D.M. Levinson, and D.W. Riffle.* USVA Med. Ctr., Kansas City, MO 64128, and Univ. of KS School of Medicine, Kansas City, KS 66103.

Human subjects were studied in attempts to confirm and extend data on evoked potentials (EPs) reported earlier by Bruce-Wolfe, et al. (BEMS Abstracts, 1981, 3, p. 59). In Exp. I, 10 young male athletes exercised vigorously in vapor-barrier suits, then were clad in thermal blankets until a moderate ΔT at the tympanum was induced ($\Delta\overline{T}$ = +1.2 °C). Ten controls exercised but were not invested in the special suits and blankets ($\Delta\overline{T}$, +0.1 °C). Means of latency to peak of a photic-flash EP (N1), of a visual-pattern-reversal-EP (P100), and of a sonically evoked, event-related EP (P300) decreased reliably from baseline values under warming, yielding linearly extrapolated temperature coefficients (Q'_{10}s) that range from ~1.3 (N1, P100) to ~1.8 (P300). In Exp. II, ten additional men twice yielded data on the same end points in consequence of "natural" ΔTs associated with the increment between early AM and later PM measurements. Although respective Q'_{10}s of the N1, P100, and P300 EPs are similar to those observed in Exp. I, a notable difference was observed in an in situ psychometric assay: Acute levels of anxiety, hostility, and depression were moderately but selectively elevated in the warmed subjects of Exp. I. The disparity in Q'_{10}s between photically and sonically evoked EPs is probably due, at least in part, to the inherently lower Q_{10}s associated with photochemical rate processes of the visual receptors.

GJ-8 ATP DEPRESSION IN PHYSARUM AMOEBAE EXPOSED TO 60 HZ SINUSOIDAL OR PULSED FIELDS. B. Greenebaum, E. M. Goodman, and M. T. Marron. Biomedical Research Institute, University of Wisconsin-Parkside, Kenosha, WI 53141

The haploid amoeboid stage of the slime mold Physarum polycephalum has been exposed continuously to a variety of electromagnetic fields (EMF); the ATP levels in non-exposed control and EMF-exposed cultures were compared. In independent experiments amoebae were exposed to 60 Hz cw electric (1.0 V/m rms), 60 Hz cw magnetic fields (.0001 T rms), and combined 60 Hz electric and magnetic fields of the same magnitude. In other experiments amoebae were exposed to pulsed magnetic fields similar to those used in stimulating bone fracture repair (EBI Inc. generator using a pulse burst waveform). The duration of EMF exposure varied from 120 to 420 days for the 60 Hz cw fields and was 48 hours for the pulsed fields. In all experiments, ATP levels in cells exposed to EMF were significantly depressed compared to controls.

GJ-10 MOBILIZATION OF CONCANAVALIN A (con A) RECEPTORS IN PULSED ELECTRIC FIELDS. S. Lin-Liu, M.M. Poo*+, E.M. Helm* and W.R. Adey. Dept. of Physiology, Loma Linda Univ. and VAMC, Loma Linda, CA 92357; +Dept. of Physiology & Biophysics, University of California at Irvine, Irvine, CA 92717.

We studied cell surface con A receptor redistribution in response to pulsed electric fields in frequency range 0.5-10k Hz. Emphasis was placed at 0.5-100 Hz, a range of biological interest. Cultured spherical myoblasts from Xenopus laevis embryos were exposed to monopolar electric fields of various pulse width, interpulse interval (IPI), frequency and intensity. Con A receptors were labeled with fluorescence-conjugated con A immediately following field exposure. The intensity of fluorescence was then determined by microfluorimeter. We found that the pre-field uniform distribution of receptors became polarized toward the cathodal pole, as in static fields. The extent of asymmetry depended on above parameters. Steady state was reached after 20 m exposure. Asymmetry induced by pulsed fields was compared with that induced by DC fields of the same average intensity. While at steady state the efficacy of the pulsed fields always approached that of the DC fields, short term responses showed dependence on IPI. Long IPI hindered development of asymmetry. Symmetrical bipolar pulses did not induce asymmetry of receptor distribution. Since bipolar fields may be considered as alternating monopolar fields of opposite polarities, we will determine whether asymmetrical fields which produce a zero net current per cycle may disturb receptor distribution. (Department of Energy and Bureau of Radiological Health)

GJ-12 EFFECTS OF 2.45 GHz MICROWAVES ON MOUSE EMBRYOS. Wallace Friedberg, Donald N. Faulkner*, and Lorrenza Snyder*. Civil Aeromedical Institute, Federal Aviation Administration, Oklahoma City, OK 73125

We investigated effects on prenatal development of 6 hours exposure to 2.45 GHz, CW, microwaves. Pregnant CD-1 mice were irradiated 8 days after conception (gestation day 8) when the embryos were in a developmental stage that is highly vulnerable to induction of anophthalmia and exencephalia. Microwave power densities of 10, 21, 24, and 32 mW/cm^2 were used. With each group of animals exposed to microwaves, control animals were sham irradiated. The mice were killed on gestation day 16 and the embryos were fixed in 10 percent buffered formalin for subsequent examination. In the 219 litters that had been sham irradiated and the 228 treated with microwaves, there were no embryos with anophthalmia. Exencephalia was observed in one sham-irradiated embryo and in eight embryos (3 litters) that had been exposed to microwaves. The estimated microwave-induced prenatal mortality ranged from 1 percent at 10 mW/cm^2 to 3 percent at 32 mW/cm^2.

GJ-14 LONG-TERM IN UTERO EXPOSURE OF MICE TO 2450 MHz CW MICROWAVE FIELDS. Mary Ellen O'Connor, David A. Bartsch*, John C. Proksa*, and Monica Indart*. University of Tulsa, Tulsa, Oklahoma 74104

Reduced body mass has been reported in mice exposed throughout the gestational period to 2450-MHz CW microwave fields. This series of experiments was designed to partially replicate and extend this finding. Sperm-positive CF1 mice were exposed for 18 successive days for 6 hours each day at power intensities of 0, 10, or 30 mW/cm^2. Additional subjects were used as cage controls. Exposure occurred in an anechoic chamber with 50% relative humidity and an ambient temperature of 22°C. Following the 18th exposure Caesarean sections were performed and the litters were observed for implantations, live fetuses, resorptions, and structural anomalies. Fetal body and brain mass was assessed and every third fetus was placed in KOH for clearing and staining. Subsequently these fetuses were evaluated for skeletal maturity using skeletal structure, number of ribs and sternal ossifications. With reference to body mass, the mice exposed to 30 mW/cm^2 were smaller than the control group but the sham (0 mW/cm^2) group was the smallest of all. Subsequent groups of mice were exposed to 0 or 30 mW/cm^2 at ambient temperatures of 25 °C. The average litter mass was lowest in the animals exposed at 30 mW/cm^2 and the sham group did not differ from the cage control group. We propose that the sham group exposed for six hours at 22 °C experienced a form of cold stress.

GJ-16 ABSENCE OF RADIOFREQUENCY RADIATION (RFR) EFFECTS AT LOW POWER DENSITIES ON DNA REPAIR IN HUMAN CELLS. David N. Erwin, Kathy Walker*+, and Martin L. Meltz*+. USAF School of Aerospace Medicine, Brooks AFB, TX 78235, and +Dept of Radiology, University of Texas Health Science Center, San Antonio, TX 78284.

Theory suggests that RFR at microwave frequencies may be absorbed in small regions of DNA molecules, causing momentary perturbations of the DNA. The recognition of UV damage in DNA and subsequent steps of DNA repair provide several opportunities for such a disturbance. We have investigated whether RFR at selected frequencies and modes has any effect on UV-induced DNA repair in normal human MRC-5 fibroblast cells measured using a DNA repair replication protocol. In summary, at 37 degrees C, exposures at 350 MHz, 850 MHz, and 1.2 GHz, with average power densities of either 1 or 10 mW/cm^2, and for both continuous wave and pulsed wave modes, no significant effect on UV-induced DNA repair synthesis was observed. SAR values were 0.04 and 0.4 W/kg at 350 MHz; 0.4 and 4.0 W/kg at 850 MHz; and 0.6 and 6.0 W/kg at 1.2 GHz. At 350 MHz and 850 MHz frequencies, for PW exposures at 39 degreee C and with average power densities of either 1 mW/cm^2 (850 MHz), 5 mW/cm^2 (350 MHz) or 10 mW/cm^2 (350 and 850 MHz), no significant effect was observed. Experiments at 39 degrees C and 1.2 GHz are in progrese. (Supported by USAF Contract #F33615-80-C-0607.)

GJ-18 EFFECTS OF MICROWAVE ON IMMUNE SYSTEM. Shao Binjie*, Chiang Huai, Wang Yifu* and Lou Yan*. Microwave Institute, Zhejiang Medical University, Hangzhou 310006 China

Kunming young adult mice were exposed to 3 GHz (PW) microwave for 60 min once a day for 2 successive days at 7 mW/cm^2. On the third day after radiation SRBC were injected into peritoneal cavities, and hemagglutinin titer (HAT) test were conducted on days 7,8,9 and 22 after radiation. A tendency of increase in HAT in exposed mice was observed on day 7, maximum increase ($p<0.01$) on day 8, beginning to decrease on day 9, and decrease to the level of sham-radiated group on 22nd day. Other young, youn adult and adult mice were exposed (5 mW/cm^2) and tested as before. No significant difference was observed in young mice, but significant ($p<0.005$) increases in HAT in the other two groups. And other young adult mice exposed to 1,5,7 and 12 mW/cm^2 MW were tested, and marked increases in HAT in 5,7 and 12 mW/cm^2 groups occurred.

GJ-20 EFFECTS OF MICROWAVE-EXPOSURE AND TEMPERATURE ON SURVIVAL OF MICE INFECTED WITH STREPTOCOCCUS PNEUMONIAE. Charles G. Liddle, Julia P. Putnam*, and Ora H. Lewter*, Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711

The combined effect of various ambient temperetures and microwave exposure was studied on mice infected with Streptococcus pneumoniea. Animals were injected intraperitoneally with an LD/50 dose of S. pneumoniae and then exposed to 2.45-GHz CW microwaves four hours per day for five days at ambient temperetures from 19-37°C and the mortality was compared to simultaneously sham-irradieted animals. As ambient temperature increased, survival among the sham-irradiated animals increased and then decreased as the thermal load increased. The same initial increase in survival followed by a decrease was also seen in the microwave-exposed animals (10 mW/cm^2, calculated SAR = 6.8 mW/gm). At all but the highest temperatures the survival rate was significantly higher in the microwave exposed animals. The survival rate among the sham-irradieted animals never reached that of the microwave-exposed animals indicating that the microwaves or the hyperthermia from the microwaves produces greater survival than heating from warm air alone.

GJ-22VIRICIDAL ACTIVATION OF HAMSTER PERITONEAL MACROPHAGES BY MICROWAVE EXPOSURE: POSSIBLE ROLE OF BACTERIAL ENDOTOXIN. G. V. RemaRao, W.A.F. Tompkins, and C. A. Cain, University of Illinois et Urbane-Champaign, Urbena, IL 61801

In previous studies we have shown that acute exposure of hamsters to microwave energy (2.45 GHz, 25 mW/cm^2, 1h) results in activation of peritoneal macrophages (PM) to a viricidal stete (Bioelectromagnetics, in press). We are testing the hypothesis thet thermogenic microweve exposure results in the release of endotoxin ecross intestinal epitheliel barriors. A number of reports have demonstreted thet endotoxin alone or in conjunction with T-cell lymphokines (LK) is capable of ectivating murine macrophages. In this study, employing verious treatment times, doses, end combinations of endotoxin and LK treetments, we found that neither agent alone or in combination was cepable of inducing tumoricidel macrophages in vitro. However, endotoxin caused activation of hamster peritoneal macrophages (PM) to a viricidal stete restricting the growth of vesicular stomatitis virus (VSV). A dose of 200 ng in vitro and 500 ng in vivo activeted the PM to the viricidal state. 500 ng of endotoxin activeted PM in vivo as early as 1 hr after peritoneal injection and the PM remained ective for 2 days.

GJ-24DISTRIBUTION OF LABEL IN STUDIES ON THE EFFECTS OF NONIONIZING RADIATION ON THE ASSOCIATION OF CALCIUM IONS WITH BRAIN TISSUE. Carl F. Blackman[1] and Blake S. Wilson[2], [1]U.S. Environmental Protection Agency and [2]Reseerch Triengle Institute, Research Triangle Park, NC 27711.

Previous experiments conducted in our leboretory end elsewhere have shown thet electromagnetic (EM) fields induce changes in the associetion of celcium ions with chick brain tissue in vitro. We have now undertaken studies using eutoradiogrephy to determine the distribution of radioactive celcium ions in the tissue just prior to exposure to the EM fields. Standard procedures were used in tissue preperation, cryogenic sectioning and exposure of photogrephic emulsions. Our results demonstrete thet the surfeces of all exterior brain structures were lebeled. Diffusion appears to govern the entry of the lebel into the brain; the interior, greeter than 1 mm from the surface, was free of label. There wes no evidence of selective labeling of layers in cortex. Labeled areas, in the order of most intense to least intense, were: 1. optic chiesm, 2. choroid plexus and venticles, 3. cerebeller, brainstem and corticel surfaces, 4. hypothalamic erea. Enhenced label over blood vessels indicated sequestering of calcium by blood constituents which may be largely responsible for the more dense labeling in the choroid plexus end nuclei of the hypothalemus. We conclude the EM fields must act either at the outer 1 mm of the surfece or within the vescular space to enhance the efflux of celcium from brein tissue.

GJ-26 EFFECT OF EXPOSURE OF ACETYLCHOLINESTERASE TO 2450-MHz MICROWAVE RADIATION. David B. Millar*, John P. Christopher*, John Hunter*, and Stephen S. Yeandle*. Naval Medical Research Institute, Bethesda, Maryland 20814.

The effect of 2450-MHz pulsed microwave radiation on the enzyme activity of membrane free acetylcholinesterase (ACHE), (isolated from Narcine brasiliensis) has been studied while the enzyme was in the microwave field. Measurements of enzyme activity at 25 °C were carried out in a quartz fibre optics linked modular spectrophotometer with a microwave microstrip, having a cell volume of about 0.2 cc. Enzyme and substrates (modified Ellman method) were recirculated (10 ml/mm) through the cell and thermostatted jackets. Total circulating volume was about four ml. We demonstrated that residence time of a volume element (cell volume/flow rate) was not critical since residence times of 0.02 to infinity, with an average SAR of 4.8 W/g, showed no loss of enzymatic activity. Further, average SAR ranging from 0.013 to 4.3 W/g (residence time 0.02) over a wide variety of pulse widths at 25 and 37 °C also induced no loss in enzyme activity. Finally, with repetition rates of 10 to 90 pulses/s, a duty cycle of 0.0004 and a SAR of 1.9 W/g, a statistically significant but marginal (2-3%) loss of activity occurs between repetition rates of 20-60 pulses/s/ We conclude that reported in vivo loss of ACHE does not arise by simple, direct interaction of microwave radiation with ACHE. (Supported by NMRD&C Work Unit MR0411.05.0005).

GJ-28 BRAIN TEMPERATURE PROFILES IN RATS DURING MICROWAVE AND ELEVATED AMBIENT AIR EXPOSURES. Thomas R. Ward and David J. Svensgaard, Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711

We have measured the changes in core and brain temperature in rats during whole body exposure to microwave radiation (2450 MHz) and elevated ambient air temperatures. In order to measure these temperature changes with and without blood flow and metabolic heat input, rata were first exposed live then sacrified and exposed again. Whether the source of heat input to an animal is metabolic, microwave or through changes in ambient air temperature, the animal will be heated non-uniformly. The heat is distributed by blood flow and conduction, but not necessarily in a uniform manner. In this study, male rats were anesthetized with pentobarbital and a non-perturbing temperature probe was placed in one of three brain locations: cerebral cortex, hypothalamus or cerebellum. A second probe was inserted 6 cm rectally to measure core temperature. The animals were equilibrated for 30 min at 22°C then exposed for 30 min to 30 mW/cm^2 (6 W/kg). The animals were subsequently sacrificed with an intracardial injection of pentabarbital. The equilibration and exposure procedures were immediately repeated on the animal carcasses. A parallel study was also conducted where an ambient temperature of 40°C was substituted for the microwave exposure. The change in temperature was measured during intervals throughout the exposures. Comparisons were drawn between the microwave and elevated ambient air trestments of both live and recently sacrificed rats.

GJ-30 ULTRASTRUCTURAL OBSERVATION OF LOW LEVEL MICROWAVE (PW) INDUCED CHANGES IN HYPOTHALAMIC NEURONS OF MICE. Yao Gengdong* and Chiang Huai. Zhejiang Medical University, Hangzhou 310006 China

C57BL infant mice (15 days) were irradiated with 3,000 MHz (PW) microwave at 1 and 5 mW/cm^2 (10 mice each) 3 hours daily for suocessive 35 days. Ten mice were sham-irradiated as control. Mice were sacrificed immediately after the exposure period. The results showed that the damage mainly occurred in the form of breaks in mitochondrial membranes and loss of normal pattern in cristae. It appeared in 8 mice of 5 mW/cm^2 group and 3 mice of 1 mW/cm^2. Mitochondrial cristae decreassd in 5 mice of 1 mW/cm^2 and only 2 mice in control, and appeared normal in the remainder. In addition, there was a distinct scarcity of rough endoplasmic reticulum and polyribosome in 3 mice of 5 mW/cm^2. A few myslin figures were detected in the two irradiated groups and control.

GJ-32 THERMAL RESPONSES OF RATS INTERMITTENTLY EXPOSED TO 2.8, 5.6, and 9.3 GHz CONTINUOUS WAVE AND PULSED RADIOFREQUENCY RADIATION. Melvin R. Frei*, Ferdinand Heinmets*, and James R. Jauchem*. Trinity University, San Antonio, Texas 78284 and Technology Incorporated, San Antonio, TX 78216

Anesthetized female rats were exposed individually to 60 mW/cm^2 continuous wave (CW) or pulsed radiofrequency radiation (RFR) at three different carrier frequenciea: 2.8, 5.6, and 9.3 GHz. During pulsed exposure, 1 and 2 us pulse durations were used at repetition rates of 250 and 500 pps. Intermittent exposures were performed to produce multiple 1°C colonic temperature cycles (generally between 38.5 and 39.5°C). When a 1°C temperature increase was achieved (during the time course, t_r), RFR was discontinued until the core temperature returned to the initial value (during the time course, t_d). The mean t_rs of rats irradiated at 2.8, 5.6, and 9.3 GHz were similar; however, a direct relationship between carrier frequency and t_d waa noted; the t_d at lower frequencies was shorter than at higher frequencies. The effects noted appeared to be independent of the pulse duration or repetition rate used during exposure. Results indicate that the carrier frequency used during RFR exposure may affect the rat's thermal responses to RFR. (Work performed at the USAF School of Aerospace Medicine, Brooks AFB, TX and supported by USAF Contract No. F33615-80-C-0614.)

GJ-34 EFFECT OF ACUTE CHLORPROMAZINE ADMINISTRATION ON THERMOREGULATION DURING RADIO-FREQUENCY RADIATION. James R. Jauchem*, Melvin R. Frei*, and Ferdinand Heinmets*. Technology Incorporated, San Antonio, TX 78216 and Trinity University, San Antonio, TX 78284.

Ketamine anesthetized female rats were exposed to 2.8 GHz pulsed radiofrequency radiation (RFR) at an average power level of 60 mW/cm^2 (2 us pulse duration, 500 pulses/sec). After an exposure period sufficient to raise colonic temperature (Tc) to 39.5°C, irradiation was performed intermittently so that 1°C changes in Tc, between 38.5 and 39.5°C, resulted. Effects of acute chlorpromazine (CPZ) administration (5 mg/kg) on time courses of Tc changes were studied. Before CPZ, times for 1° increases and decreases in Tc were 7.9 $\pm$ 0.1 min (mean $\pm$ SEM; N=6) and 13.8 $\pm$ 1.5 min, respectively. After CPZ, the values were 11.5 $\pm$ 1.0 min and 9.2 $\pm$ 1.0 min, respectively. Changes in both of the time courses were statistically significant ($p < .05$). The data indicate that acute CPZ administration slows the rate of Tc increase during exposure to RFR, snd hastens the return to baseline when exposure is discontinued. (Performed at USAF School of Aerospace Medicine, Brooks AFB, TX 78235; USAF Contract #F33615-80-C-0614.)

GJ-36 BIOLOGICAL EVALUATION OF RATS EXPOSED TO LONG-TERM LOW-LEVEL PULSED RADIO-FREQUENCY RADIATION. Robert B. Johnson*, Lawrence L. Kunz, Chung-Kwang Chou and Arthur W. Guy. Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

A study designed to investigate the possible cumulative effects of exposure to 2450 MHz low-level radiofrequency radiation on rats wss completed following 25 months of exposure at a level chosen to simulate the exposure of a human to 450 MHz. This resulted in a maximum average specific absorption rate (SAR) of 0.4 W/kg. This presentation describes the animal housing and exposure facilities and the results of the physiological evaluations completed. These evaluations include clinical chemistries, corticosterone, thyroxine, protein electrophoresis, hematology, whole body analysis, immunological tests, assessment of open-field activity, oxygen consumption and carbon dioxide production and a complete histopathological evaluation.

GJ-38 EFFECTS OF 20 MHz RADIATION ON RAT HEMATOLOGY AND BLOOD CHEMISTRY. Lenora S. Wong*, Johnathan L. Kiel*, James H. Merritt*. USAF School of Aerospace Medicine, Brooks AFB, TX 78235

Little information exists in the scientific literature on the biological effects of HF-band (3-30 MHz) exposures on hematological or biochemical values. In this study, 100 male, 300 g Sprague-Dawley rats were exposed in a TEM chamber to 20 MHz continuous wave fields for 6 hr/day, 5 days/wk for 5 weeks. The average E-field intensity was 2686±164 v/m; average incident power density, 1217±98 mW/cm^2; and calculated SAR, 0.09 W/kg. Samplings obtained on days 8, 22, and 39 of the exposure period showed no statistically significant differences between exposed and control groups for any of the 16 variables of interest: body mass, splenic mass, spleen cell density, red and white blood cell counts, hematocrit, hemoglobin, methemoglobin, red cell fragility, and serum levels of bilirubin, creatinine, SGPT, alkaline phosphatase, Ca, Na, K. Statistically significant differences ($P<0.05$) were found in the Group* Day interactions of splenic mass, red cell count, and hemoglobin and indicate that while individual end points did not differ, the exposed and control groups may have behaved differently across the days of the experiment. A red blood cell population shift was observed in exposed animals, which was suggestive of a change toward macrocythem a, although the magnitude of the effect was within normal physiologic range.

GJ-40 POSSIBLE USE OF SHORT WAVES TO DETECT LUNG EDEMA. Otto Petrowicz*, Josef Eichmeier* and Günther Blümel*. Institute for Experimental Surgery, Technical Univ., Munich, FRG

There are many medical examples in intensive care or in the early postoperative phase were the knowledge of lung water content is of critical importance. The purpose of this report is to suggest a method that is simple, objective, and reproducible and allows to measure the severity of lung edema development.

The technique is based on the dispersion of the complex relative dielectric constant. With respect to the water content φ and the frequency f, available date from the literature for ε_r and of own in vitro measurements were compiled to produce a continuous function $\varepsilon_r(\varphi,f)$ over a frequency range from 1 MHz to 100 MHz. A homogenious electrical field orthogonal to the layers of a plane layer model, representing the different kinds of tissue in the human thorax, as well as different arrangements in layers with changeing water content were assumed. The following results were be obtained.

1. The estimated water content $\varphi_{est.} = k \cdot d\varepsilon_r/df$ shows the best approximation to the assumed water content of the layer which represents the lung.
2. The most favourable frequency range with the lowest error is between 20 and 30 MHz.

Additional profit in contrast to actual methods using RF are less problems with the penetration depth in biological tissue, reflections on layer surfaces and all other mechanical and electrical problems using higher frequencies. With these preconditions a measuring device was realized. In vitro and in vivo experiments on rabbits were carried out which could demonstrate the presumed accuracy.

GJ-42 DIELECTRIC PROPERTIES OF FROG TISSUES IN VIVO AND IN VITRO AT FREQUENCIES 200 MHz-8.0 GHz. Jean-Louis Schwartz* and Geoffrey A.R. Mealing*, Division of Biological Sciences, National Research Council, Ottawa, Ontario, Canada, K1A 0R6.

The relative dielectric constants and the conductivity of several tissues and the blood of the bullfrog Rana Catesbeina (abdomen skin, skeletal muscle and heart) were measured at frequencies between 200 MHz and 8 GHz both in vivo and in vitro using an open-ended coaxial line probe in conjunction with an automatic network analyzer (Stuchly, M.A. and Stuchly, S.S., IEEE Trans. Instr. Meas. IM 29:176-183, 1980). The results were compared to published data on dielectric properties of various tissues of the same and other species (amphibians, invertebrates and mammals). It was found that the relative dielectric constant of frog skeletal muscle was similar to those of other species; the conductivity was however smaller than for the barnacle. Although published data are sparse on heart, it appeared that frog heart dielectric properties are in the same range. In vivo data on frog heart were larger than those obtained in vitro. The values obtained for frog skin were comparable to those of human skin. The same results were obtained for blood.

GJ-44 FORMULAS FOR PREPARING PHANTOM MUSCLE TISSUES AT VARIOUS RADIOFREQUENCIES. Chung-Kwang Chou, Gang-Wu Chen*+, Arthur William Guy and Kenneth H. Luk*. Bioelectromagnetics Research Laboratory, Departments of Rehabilitation Medicine and Radiation Oncology, University of Washington, Seattle, WA 98195

High-water content phantom tissues for various radio frequencies are needed for dosimetry studies relating to treatment of cancer by RF heating. Materials for 915 and 2450 MHz developed in this laboratory have been widely used around the world. Treatment of tumors to radio frequency waves must be done at widely different frequencies for an optimum heating pattern for a particular location or tissue depth. The ingredients of the phantom tissues are water, polyetheline power, gelling agent, and sodium chloride. Using a temperature controlled slotted line method, proportions of the ingredients for phantom materials simulating human high-water content tissues at 13.65, 27.12, 50, 70, 100, 200, 300, 433, 500, 600, 700 and 800 MHz are obtained. The variations in dielectric constant and conductivity of these materials at different temperatures (15, 22, 30° C) are also characterized.

+Gang-Wu Chen is a Visiting Scientist from Shandong University, People's Republic of China

GJ-46 THERMOREGULATION DURING MICROWAVE RADIATION INDUCED HOTSPOTS IN THE RAT: COMPARISON OF RADIATION FREQUENCY AND SAR. R. Y. Emmerson*, J. A. D'Andrea, and J. R. DeWitt*. Departments of Electrical Engineering, Bioengineering, and Psychology, University of Utah, Salt Lake City, Utah 84112.

Dosimetric studies with the rat carcass have revealed intense hotspots in the body and tail of the rat exposed to microwave radiation. It is important to ascertain whether a thermoregulating rat could prevent heat buildup in the hotspot. Rats, anesthetized with ketamine hydrochloride, were used to determine the effect of bloodflow and physiological thermoregulation during microwave radiation exposure. Temperature during microwave radiation exposure, at anatomical hotspot sites, was monitored by a fiber-optic semiconductor temperature monitor. Rats were exposed to either 360 MHz, 700 MHz, 915 MHz, or 2450 MHz microwave radistion at whole-body SAR's of 2 W/kg, 6 W/kg, or 10 W/kg. At the higher SAR's, heat buildup was evident with rate of heating proportional to the SAR of the hotspot site.

GJ-48 MICROWAVE ABSORPTION EFFICIENCY OF HUMAN EYE BY HIGHER ORDER FINITE ELEMENTS. Dr. S.C. Gupta and A. Sreenivasan, Department of Electronics and Communication Engineering, University of Roorkee, Roorkee, INDIA.

Using an axisymmetric inhomogeneous complex dielectric model of human eye, microwave absorption characteristics has been predicted. Higher order finite elements have been used in the estimation of microwave absorption efficiency for the two orthogonal polarizations. Results have been compared with the extending Boundary Condition Method.

GJ-50 CALCULATIONS OF SPECIFIC ABSORPTION RATE DISTRIBUTIONS INSIDE A CYLINDER USING GEOMETRICAL OPTICS. Luis G. Lozsno and William D. Hurt. USAF School of Aerospace Medicine, Radiation Sciences Division, Brooks AFB, Texas 78325.

Geometrical optics offers a simplified view for understanding how a high frequency electromagnetic wave penetrates a body. Using this approach, localized specific absorption rate (SARs) for a cylinder were calculated and plotted, thus giving sn SAR distribution inside the body. For comparison, these localized SARs were summed up and a value for the average whole body SAR was obtained. This method offers a good approximation of where inside the cylinder the energy is deposited.

GJ-52 EXTREMELY LOW FREQUENCY ELECTROMAGNETIC EMISSIONS FROM VIDEO DISPLAY TERMINALS AND OTHER DEVICES. Maria A. Stuchly and D.W. Lecuyer*, Radiation Protection Buresu, Health and Welfare Canada, Ottaws, Ontario, K1A OL2.

Because of the widespread and continuously increasing use of video displsy terminals (VDTs), all electromagnetic emissions from these devices should be assessed whether they pose s potential heslth hszard. The magnetic field intensity and the frequency spectrum of the emissions were messured in the range of 5-500 Hz for s few VDTs and other typical electricsl devices commonly found in offices and homes. The frequency spectrum and the field intensities were compared with those capable of causing biological effects. The emissions from VDTs were at the power line frequency of 60 Hz and its harmonics and the intensities were comparsble to those sround other devices e.g. fluorescent lights, electric typewriter, hsir dryer, baseboard heater. The ELF fields sround VDTs were st least s thousand times less than those shown to cause potentially hazardous biologicsl effects.

GJ-54 HUMAN EXPOSURE FACILITY FOR DOUBLE-BLIND TESTING OF 60 Hz ELECTRIC AND MAGNETIC FIELDS. Hsrvey D. Cohen snd Chsrles Graham. Midwest Resesrch Institute, Kansas City, MO 64110

As part of a larger research program, MRI is constructing a lahorstory facility specificslly designed for the safe testing of humans exposed to 60 Hz electric and magnetic fields under double-blind conditions. When completed in the near future, the facility will have the following chsrscteristica and cspabilities: (1) generation of uniform electric fields with minimal hsrmonic distortion in the rsnge 0 to 20 kV/m; (2) vertically rotating, uniform msgnetic fields, phased to maximize the vector product of the two fields, in the rsnge 0 to 32 amperes/m (0-0.4 gauss); (3) environmentsl control systems for temperature, humidity, acoustic noise, vibration and air sampling analysis; (4) systems to present real snd sham fields; and (5) the physical sppearance of a typical office (paneled wslls, indirect overhead lighting and carpeted floor) so as not to induce anxiety or stress simply ss s function of design. An audio/visual presentstion will be used to describe this unique facility. The problems snd solutions involved in electric safety, double-blind controls snd materials selection, among others, will be discussed. (Supported by Contract No. 21082-03, New York State Lepsrtment of Health.)

GJ-56 GENERATION AND MEASUREMENT OF LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS FOR BIOLOGICAL EFFECT STUDIES. Melvin J. Johnson, Southwest Resesrch Institute, P. O. Drawer 28510, San Antonio, Texas 78284.

Studies of the biological effects of low frequency electric and magnetic fields require that the field exposure level be accurately generated and measured. Techniques for the generation and measurement of field levels are discussed with particular attention to those of high voltage 60 Hz power transmission lines. Included are helmholtz coils for the generation of magnetic fields, simulation of electric fields by conduction through a media, electrically small sensors, and fiber optic sensing systems.

GJ-58 MICROWAVE HEATING OF BIOLOGICAL PLANE LAYERS AND NON-LINEAR THERMOREGULATORY EFFECTS.

S.Caorsi*. Biophysical and Electronic Engineering Division, Electronic Engineering Dept. 16145 Genoa, Italy.

The application of electromagnetic fields to the hyperthermic treatment of cancerous tissues poses many problems concerning the biological, clinical and also electromagnetic aspects that are related to heating. As fas as electromagnetic aspects are concerned, we asaume that a biological aystem can be aimulated by a series of plane layers. Furthermore, besides the cooling of the external aurfaces, we consider the thermoregulatory properties of the body both of the chemical type (i.e., metabolic heat generation), and of the physical type (i.e., variations in the blood flow). In order to approximate as much as possible the actual behaviour of the biological system, the thermoregulatory properties are assumed to be non-linear functions of the local temperature v(x). As a first approach, we have operated a segment-linearization process of such functions; In thia way, we have pointed out various threshold temperatures that diversify in linear ranges the behaviour of the thermoregulatory functions. The calculation of the space-time evolutions of temperature distributions has been performed using a numerical program that has been developed by applying the technique of finite differences.

GJ-60 ANALYSIS OF THE HELICAL-COIL APPLICATOR FOR HYPERTHERMIA,

M. J. Hagmann and R. L. Levin*, BEIB/DRS, National Institutes of Health, Bethesda, MD 20205

Experimental results have previously been presented showing the helical-coil permits near-uniform heating over the cross-section of a cylindrical phantom. We have used analytical methods to model the electromagnetic interaction of a helical-coil with layered cylindrical models representing the human upper arm and thigh. Analytical methods have also been used to solve the bioheat transfer equation for a cylindrical model of the arm within a helical-coil of finite length. The effects of each coil parameter on heating pattern and coupling efficiency have been determined. Temperature distributions have been determined for both transient and steady-state conditions.

GJ-62 AN ANSI RADIATION PROTECTION GUIDE CONFORMAL PROBE. Edward Aslan, Narda Microwave Corporation, Hauppauge, New York 11788

The ANSI C95-1-1982 Standard has designated safety levels that are frequency dependent. An electromagnetic radiation probe has been designed with various sensing means to create a sensitivity vs. frequency that is the inverse of the A.N.S.I. protection guide over the frequency range of 300 KHz thru 2 GHz. The fraction of the safe level incurred within each frequency interval is determined and integrated to provide a read out in percent of the standard. True square law sensor characteristic provide the probe with isotropic performance, the ability to add multiple frequencies sources and independence of modulation form. The probe is compatible with Narda's existing power density monitors.

GJ-64BROADBAND, TEMPERATURE DEPENDENT MM-WAVE SPECTROSCOPY USING AN UNTUNED CAVITY. F. Kremer, A. Poglitsch, L. Genzel. Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 7000 Stuttgart 80, Federal Republic of Germany.

A method is described, which provides the possibility for broadband spectroscopy in the frequency range from 40 to 170 GHz and at temperatures between 4.2 K and 400 K. In particular it is suitable for measurements on inhomogeneous and scattering samples, like proteins, which are usually obtained in a powder form. An approximately isotropic and homogeneous field is created inside a high-Q- greatly oversized resonator by supplying radiation from an appropriate tunable source. The Q of such a multimode resonator is only slightly dependent on the frequency as long as the wavelength remains very small relative to the cavity dimensions and the isotropy and homogeneity of the field can be enhanced by use of a mechanical mode stirrer. The sample to be measured is introduced into the cavity and the resultant change in Q can easily be measured with good precision. Since any radiation scattered or reflected by the sample is returned to the cavity the measured loss is entirely due to absorption. For measurements at liquid helium-temperature a special cryostat is used, such that the total sample chamber inside the cavity is made out of fused silica which is nearly transparent for microwaves.

GJ-66REDUCTION OF RF LEAKAGE FIELDS FROM PLASTIC SEALERS. Kjell Hansson Mild and Arne Erikason*, National Board of Occupational Ssfety and Health, Occupstional Health Depsrtment, Umeå, Sweden.

Workers nesr RF dielectric plastic aealers are often exposed to RF leskage fields of levels that widely exceed the preaent occupstional atsndard. Many production processes are such that the whole electrode ayatem may be totally shielded, thereby reducing the RF leaksge to a minimum. However, there sre proceasea where thia measure is impoaaible to take because of for example a demand for viausl aupervisaion of the process, the material takes up a lot of apsce, frequent ahifts of electrodes due to ahort production aeries. In theae cssea the sealer has to be of an open type. Measurements of E- snd H-fields ahow that the Swediah threshold valuea are exceeded nesr many auch sealera at distsncea up to 1 m. In order to reduce the RF leskage fields from these aealera the electrode ayatem snd the machine layout have to be modified. We have found thst in those casea where a aufficiently large cspscitive deflective ahielding can be plsced immedistely in front of or behind the electrode astisfsctory reduction of the RF expoaure can be obtained. Alao other messures have auccessfully been tried, such aa a new type of coaxisl electrode syatem.

SESSION K Physiological Effects

Cochairs: **M. I. Rudnev and L. L. Kunz**

K-1 REGISTRATION OF SOME PHYSIOLOGICAL REACTIONS IN RATS UNDER THE EFFECTS OF ELECTROSTATIC FIELD FROM NEGATIVE POLARITY CHARGES. V.Ya.Akimenko, S.M.Vishnyak, N.G.Belonozhko, I.S.Bezdolnaya, A.N.Grin. Kiev A.N.Marzeev Scientific Research Institute of General and Communal Hygiene, Popudrenko 50, Kiev-252160, USSR

White Wistar rats wereexposed to 100 kV/m electrostatic field (negative polarity charges) during 30 days 6 hours dayly, 5 days per week in the conditions of individual exposure. Registered were behavioral indices (according to the open field test) and cell immunity (according to lymphocyte blast-transformation reaction) in the animals of both experimental and control groups. Electrostatic field was found to be percepted by rats, causing changes in their motor activity. As to cell immunity no significant changes were observed. It is supposed that the effects observed are connected with the animals orientation response to piloerection in electrostatic field conditions.

K-2 ELF RADIATION AND NATURAL KILLER CELL ACTIVITY. R. John Garner, Marie M. Riddle*, Ronald R. Rogers*, Denise G. Rowe* and Ralph J. Smislowicz, Health Effects Research Laboratory, US Environmental Protection Agency, Reseesrch Triangle Park, NC 27711

Preliminary studies indicsted a possible enhancement by ELF radistion of mouse natural killer (NK) cell sctivity in vivo as measured by clearance of i/v injected tumor cells. Further investigstion at one apparently effective frequency/intensity combination, 15 Hz and 20 v/m peak-to-peak, yielded equivocal results. Analysis of the dats suggested thst age at exposure and intervsl between injection of target cells and initistion of exposure determined the response observed. However, with careful control of these factors, results continue to be unpredictable. The work is being extended to other intensities and frequencies.

K-3 BEHAVIORAL AND AUTONOMIC THERMOREGULATION IN HAMSTERS DURING MICROWAVE EXPOSURE. Christopher J. Gordon and Merritt D. Long. Physiology Section, Biological Engineering Branch, Experimental Biology Division, Health Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711

Preferred ambient temperature (TA) and breathing rate were measured in free-moving hamsters exposed to 2450-MHz microwaves. A waveguide exposure system was imposed with a longitudinal temperature gradient which allowed hamsters to select their preferred TA. Breathing rate was monitored remotely by analyzing the rhythmic shifts in unabsorbed microwave energy passing through the animal. Without microwave exposure hamsters selected an average TA of 30 °C. This preferred TA did not change until the rate of heat absorption from microwave exposure exceeded approximately 1.2 W/kg. Hamsters maintained their breathing rate at baseline levels by selecting a cooler TA during microwave exposure. In contrast, hamsters maintained at a TA of 30 °C (without a temperature gradient) underwent a sharp increase in breathing rate compared to animals allowed to select their own TA. These data support previous studies suggesting that behavioral thermoregulation (i.e., preferred TA) is most sensitive to thermal stress compared to autonomic thermoregulation (i.e., breathing rate). It is apparent that selecting a cooler TA is a more efficient and/or effective means of dissipating a heat load accrued from microwave exposure.

K-4 DIFFERENCES OF BRAIN AND RECTAL TEMPERATURE DURING 918 MHz MICROWAVE EXPOSURE. Dennis L. Hjerssen end A.W. Guy. Departments of Psychology and Rehabilitation Medicine, University of Weshington, Seettle, WA 98195

Pursuant to our development of e microweve hyperthermia model of febrile convulsions ws have escertained deep brain and rectal temperetures of neonatal rat pups before during, and after microwsve irradistion. The pups were culled from five litters and wers tested at 11, 13, 15 or 17 days postpartum (n = 5 per ags). Each pup was removed from its dam, weighed and quickly enesthetized with Halothsne ges. The skin and calvaria were punctured by en 18-ga needle 0.5 cm lateral to midline and superior to the crest of the occipital bone. The tip of a Vitek Model-101 thermocouple probe was inserted 1.2 cm pest the puncture on s line parallel with the longitudinal fissurs. The tip of a aecond Vitek probe was inserted 1.5 cm beyond the rat's anus. Ths rat was plece in the centerline of a circularly poleraized waveguide. Temperatures wers recorded at 30-a intervals for a 5 min equilibretion period, during 10 min of microwave irrediation (918 MHz, CW, SAR = .378 W/kg) end for 10 min following irradiation. At all ages, rsctal temperature increased et a faster rate thsn deep brain tempereture and reached higher peak temperatures, suggesting e thermal brein spering mechanism. Rats et all ages retain significent termal energy during the period following irredietion.

K-5 BIOLOGICAL EVALUATION OF RATS EXPOSED TO LONG-TERM LOW-LEVEL PULSED RADIOFREQUENCY RADIATION (PART 1). Robert B. Johnson, Lawrence L. Kunz, Chung-Kwang Chou and Arthur W. Guy. Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

A study designed to investigate the possible cumulative effects of exposure to 2450 MHz low-level radiofrequency radiation on rats was completed following 25 months of exposure. This presentation describes the results of the physiological measurements made as an evaluation of cumulative metabolism including assessments of bodyweight, food and water consumption, oxygen consumption and carbon dioxide production. Also presented is an evaluation of alterations in open-field behavior and plasma corticosterone observed during the periodic assessments conducted through the course of the study.

K-6 BIOLOGICAL EVALUATION OF RATS EXPOSED TO LONG-TERM LOW-LEVEL PULSED RADIOFREQUENCY RADIATION (PART 2). Lawrence L. Kunz, Robert B. Johnson, Chung-Kwang Chou and Arthur W. Guy. Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

A study designed to investigate the possible cumulative effects of exposure to 2450 MHz low-level radiofrequency radiation on rats was completed following 25 months of exposure. This presentation describes the results of a number of immunological evaluations completed including mitogen stimulation response and B- and T-cell enumeration. These evaluations were made as part of an interim kill of 10 animals from each treatment condition and a final kill of the surviving 10 animals per treatment condition. While significant alterations of these responses were found coincident with the interim procedure, no differences were found at the final kill. A review of the histopathological evaluations completed will also be presented and discussed with respect to tumor incidence and mortality.

K-7 LIFE-TIME EXPOSURE OF CD-1 MICE TO 1-T HOMOGENEOUS AND 2-T/METER GRADIENT DC MAGNETIC FIELDS: A PROGRESS REPORT AFTER 8 MONTHS OF EXPOSURE. Bruce J. Kelman* and D. Dennis Mahlum*, Pacific Northwest Laboratory, Richland, WA 99352.

Life-time exposures of mice to magnetic fields is being conducted in a facility containing two beam-bending magnets. Each magnet has an 18-cm gap with a homogeneous (H) area of 41 X 90 cm and a usable nonhomogeneous area of 30 X 90 cm. Exposure chambers for each magnet provide equivalent temperature, humidity, lighting, and noise levels. Female Charles River CD-1 mice were placed in the exposure chambers at 5 months of age (31.2 ± 0.7 g; mean ± SD) and exposed to a 1-T H (50 mice) or a 2-T/m (25 mice) gradient (G) field. The same number of mice were placed in the chambers of the non-energized magnet to serve as sham-exposed controls. Weight gain of the mice exposed or sham-exposed to the H field was not different over the 8-month period; exposed mice weighed 39.7 ± 1 g and sham-exposed weighed 39.6 ± 0.9 g at 8 months. Weight gain of mice exposed or sham-exposed to the G field was also not different over the 8-month period; exposed mice weighed 37.0 ± 1.5 g and sham-exposed mice weighed 37.2 ± 0.9 g. At 8 months, no differences in weight gain were statistically significant. However, mice exposed and sham-exposed to G fields grew more slowly during the first 40 days of exposure than mice exposed and sham-exposed to H fields. Mortality at 8 months was 6%, 8%, and 4% in mice exposed to H, G, and both parts of the non-energized magnet, respectively. (Supported by the U.S. Dept. of Energy Contract No. DE-AC06-76RLO-1830)

K-8 RESPONSE OF HUMAN NIGHT VISION ACUITY TO EARTH MAGNETIC FIELD VARIATION. Kunibert Krause,* Gertrud Cremer-Bartels,* and Hana Joachim Küchle* Eye Hospital of the Westphalian Wilhelma Univeraity, D-4400 Münster, FRG Germany.

The horizontal component of the natural magnetic field of the earth is reversed by means of a pair of Helmholtz coila. Night vision acuity of 67 volunteers, situated in the modified magnetic field is measured by a special instrument (Mesoptometer II, Oculua, Dudenhofen, FRG). With onset of magnetic field variation the rate of incorrect reaction ia significantly increased. Thia phenomenon was confirmed in double blind atudies. On the basia of our experiments with birda we auggest that melatonin may also be involved in retinal response to magnetic field variations in humans.

K-9 CONDITIONING OF AMPHETAMINE HYPERTHERMIA WITH LOW-LEVEL MICROWAVE IRRADIATION AS THE UNCONDITIONED STIMULUS. Henry Lai*, Akira Horita*, Chung-Kwang Chou and Arthur W. Guy. Departments of Pharmacology, Psychiatry and Behavioral Sciences and Rehabilitation Medicine, University of Washington, Seattle, WA 98195

We found previously that acute low-level microwave irradiation attenuated amphetamine-induced hyperthermia in rats. In a recent experiment, rats were exposed to low-level circularly polarized microwaves (1 mW/cm^2, 2 μs, 500 pps, averaged SAR 0.6 W/kg) in individual waveguides 45 minutes a day for 10 days. Control animals were sham-irradiated simultaneously. On the 11th day, both microwave and control animals were sham-irradiated and then injected with amphetamine. The animals irradiated with microwaves (days 1-10) snd sham-irradiated on day 11 had significantly higher response than the sham-irrsdiated animals ($p<0.01$). Two additional sets of animals (microwave and sham-irradiated for 10 daily 45-minute sessions) were tested with amphetamine on day 11 without first being subjected to sham-irradiation. There was no significant difference in response between these two sets of animals. Therefore, the effect of microwave on amphetamine hyperthermia is probably conditioned to cues in the waveguide.

K-10 EFFECTS OF ACUTE LOW-LEVEL MICROWAVE IRRADIATIONS ON ETHANOL HYPOTHERMIA AND CONSUMPTION IN RATS. Henry Lai*, Akira Horita*, Chung-Kwang Chou and Arthur W. Guy. Departments of Pharmacology, Psychiatry and Behavioral Sciences and Rehabilitation Medicine, University of Washington, Seattle, WA 98195

Acute circularly polarized microwave radiation (2450 MHz, 1 mW/cm^2, 2 μs, 500 pps averaged SAR 0.6 W/kg) significantly attenuated the initial rate of fall in body temperature elicited by ethanol. In another experiment, water deprived rats were placed in individual waveguides for 45 minutes, then a drinking bottle was introduced. Fluid consumption during the next 45 minutes was recorded. Drinking bottles containing a 10% sucrose solution were provided during the first four days. From day 1-3 all animals were sham-irradiated. On day 4, half of the animals were irradiated with microwaves during the entire 90 minutes and the other half were sham-irradiated. Microwave exposure did not significantly affect the consumption of the sucrose solution. On experimental days 5-9, a 10% sucrose and 15% ethanol solution was placed in the drinking bottles. The rats were sham-irradiated on days 5-7. A steady level of fluid consumption was observed in these three day sessions. On day 8, half of the animals received 90 minutes of microwave irradiation and the other half received sham-irradiation. Microwave exposure significantly enhanced the drinking of ethanol solution.

K-11 IRRADIATION OF UNANESTHETIZED RHESUS MONKEYS WITH 9.31 GHz MICROWAVE RADIATION: A LONG-TERM STUDY. Robert D. McAfee, Ph.D., Richard R. Bishop, Ph.D., and Robert Gordon, M.D. Veterans Administration Hospital, New Orleans, LA, College of Engineering, University of New Orleans and Department of Ophthalmology, Tulane University School of Medicine, New Orleans, LA 70112

Since 1976 a group of 12 rhesus monkeys has been exposed to 9.31 GHz microwave radiation, pulsed and at an average power density of 150 and 300 mW/cm^2. Irradiation was accomplished without anesthesia by training the monkeys to operate a manipulandum which allowed them to obtain a rewarding drink of apple juice while holding a tubular mouthpiece in their mouth. This action closed a switch which then allowed the monkeys to lever press for apple juice which was delivered in a 0.2 ml increment for approximately every five lever presses. During the period of time the switch was closed, the monkeys were irradiated in the face and eyes. The radiation source is a Model AN/CPN-6 radar which produced a 0.5μ sec. pulse at a peak power of 40 kW. A standard gain horn (6 x 4.9 cm, E-field vertically polarized) was located 15 cm from the monkey's face. A SAR of 20 mW/g (at 150 mW/cm^2) and 40 mw/g (at 300 mW/cm^2) was measured at the locus of the monkey's face using a water phantom. At 6 month intervals the monkey's eyes were examined by a slit-lamp biomicroscope for lens defects. The latest examination was performed in August 1982 and to this date no lens defects have been found.

K-12 HYDROPHONE RESPONSE FROM THE BRAIN OF LIVE RHESUS MONKEYS INDUCED BY PULSED MICROWAVE IRRADIATION. Richard G. Olsen. Bioenvironmental Sciences Department, Naval Aerospace Medical Research Laboratory, Pensacola, FL 32508

To obtain further measurements of the mechanical consequences of pulsed microwave absorption in the heads of live animals, small hydrophones were implanted in the brains of rhesus monkeys (Macaca mulatta) while pulsed microwaves at either 5.66 (0.5-μs pulse width at 200 kW peak power) or 2.45 GHz (8-μs pulse width at 3 kW peak power) were applied. The hydrophones were hollow cylinders 1.27-mm OD X 6.35 mm long with a wall thickness of 0.254 mm. They were bonded to the shafts of 22-guage hypodermic needles which served as one electrical contact. Irradiation was applied either with a medical-type applicator or with a standard gain horn at close range while the response waveform of the hydrophone was being acquired from the anesthetized animals. Harmonic content of each waveform was determined with a fourier wave analyzer. Results compare favorably with those previously obtained with smaller animals and with tissue-equivalent models. The presumed fundamental mode of brain vibration was observed at both irradiation frequencies, and at 5.66 GHz, peak pressure amplitudes of hundreds of pascals were recorded. It is concluded that the human brain would respond as did the monkey brain and that megawatt or multimegawatt transmitters could produce thousands of pascals of pressure under certain conditions.

K-13 SEQUENTIAL SAMPLING IN CANNULATED RATS EXPOSED TO 60 Hz ELECTRIC FIELDS. W.J. Quinlan*, S.M. Michaelson, N.A. Lebda*, Q.A. Nguyen*, and S. Pettit*. Department of Radiation Biology and Biophysics, School of Medicine and Dentistry, University of Rochester, Rochester, NY 14642.

Male Long-Evans rats (350-400 g) with indwelling carotid cannulae were exposed for 4 hours to 80 kV/m 60 Hz sustained or interrupted electric fields. Preliminary corticosterone and prolactin results do not indicate a field effect of 80 kV/m exposure. The temporal aspects of endocrine reactions in cannulated and non-cannulated rats injected with centrally acting drugs (dopamine and naloxone) were also studied. Data will be presented on the influence of frequency of sampling of small volumes of blood in cannulated rats and regression of corticosterone and prolactin levels on drug dose for dopamine and naloxone. The importance of repeated blood sampling, blood cell reinjection, catheter manipulation, and other possible technique related artifacts in cannulated rats while in the electric field will be discussed. This work was performed under DOE contract DE-AC02-76EV03490 at the University of Rochester Department of Radiation Biology and Biophysics.

SESSION L Dosimetry II

Cochairs: Mark Hagmann and S. C. Gupta

L-1 MICROWAVE RADIATION ABSORPTION IN THE LABORATORY RAT: COMPARISON OF PRE-RESONANT, RESONANT, AND POST-RESONANT FREQUENCIES. J. A. D'Andrea, R. Y. Emmerson*, J. R. DeWitt*, and O. P. Gandhi. Departments of Electrical Engineering, Bioengineering, and Psychology, University of Utah, Salt Lake City, Utah 84112.

Whole-body and part-body absorption of microwave radiation was measured in the medium sized rat exposed to frequencies of 360 MHz, 700 MHz, 915 MHz, and 2450 MHz Exposures were conducted in an anechoic chamber under quasi-far-field exposure conditions. Dosimetric measurements were made via calorimetric techniques. Whole-body specific absorption rates (SAR) were measured using a twin-well calorimeter system. Part-body SAR was measured at various anatomical sites within the rat body using a fiber-optic semiconductor temperature monitor. Whole-body SAR at each frequency agreed very well with values predicted by the Radio Frequency Dosimetry Handbook. Part-body SAR hotspots were determined in the esophagus, rectum, and tail of the rat. These are governed by radiation frequency and orientation of the rat within the microwave field. At 360 MHz, an SAR hotspot in the rat tail exceeds the whole-body SAR by fifty times. The importance of these phenomena for behavioral and physiological experiments will be discussed.

L-2 MODELING THE THERMOPHYSIOLOGIC RESPONSE OF SQUIRREL MONKEYS EXPOSED TO RF RADIATION. Mohammed B.E. Fatmi*[1] and Ronald J. Spiegel[2], [1]Northrop Services, Inc., Health Effects Research, [2]US Environmental Protection Agency, Health Effects Research Laboratory, Research Triangle Park, NC 27711.

Because ethical considerations prohibit whole-body RF exposure of human subjects, the squirrel monkey has been chosen as a surrogate to study the thermal effects of RF radiation. Thermoregulatory profiles reveal that the squirrel monkey has a thermoregulatory system that is similar to man's. A combined EM absorption and thermoregulstory block model of a squirrel monkey has been developed. Numerical results will be presented for the case of resonant RF exposure of a squirrel monkey located over a ground plane. Some selected temperatures will be verified experimentally by exposing live monkeys to similar exposure conditions. The inhomogeneous thermal block model of a squirrel monkey consists of several hundred cells or blocks, in which the temperature is calculated at the center of each block as well as on the surface of those blocks that represent the exterior of the monkey. The thermal response model considers the standard heat transfer mechanisms (conduction, convection, and radiation) along with the thermoregulatory mechanisms of internal heat generation due to metabolism, internal heat transfer due to blood flow, and the cooling of the skin by sweating and evaporation. The thermal loading due to the energy absorbed from the EM field is calculated by a finite element EM model that can determine SAR's for both CW and transient exposure conditions.

L-3 IMPEDANCE NETWORK FORMULATION TO OBTAIN SAR DISTRIBUTIONS FOR QUASI-STATIC ELECTROMAGNETIC FIELDS - CALCULATIONS FOR 60 Hz FIELDS AND MAGNETRODES. Om P. Gandhi, John F. DeFord*, and Hiroshi Kanai*. Department of Electrical Engineering, University of Utah, Salt Lake City, Utah 84112.

2-D and 3-D impedance networks are formulated to calculate induced currents and SAR distributions for low frequency electromagnetic fields ($\lambda_\varepsilon \geq 10$ times the dimensions of the body). These networks are formulated assuming anisotropic, inhomogeneous impedivity $1/(\sigma + j\,\omega\,\varepsilon)$ where σ and ε represent the volume-averaged conductivity and dielectric constant of the tissues for the various cells, the directional averaging having been taken by means of an optical image digitizer capable of cataloging the tissue types into much finer (256x256) segments for the sections of the anatomy. For a biological body subjected to 60 Hz electric fields, the driving terms for the equivalent impedance network are the currents $j\omega\varepsilon_0 \bar{E}_{ext}$ where the external fields $\bar{E}_{ext}$ converging on the body are calculated with its representation by a metallic body recognizing the fact that internal fields are miniscule as compared to the external fields. The driving terms for magnetrode problems are the E.M.F.s created in individual loops on account of time-varying magnetic fields. Because of its simplicity, this procedure has been used for bodies subdivided into thousands of cells giving thereby the details of current and SAR distributions that are impossible with method of moments. The paper will give examples of calculated current distributions for 60 Hz fields and SAR distributions for magnetrodes.

L-4 SPECIFIC ABSORPTION RATE IN A SITTING RHESUS MODEL AT 225, 1290, AND 5950 MHz FOR E, H, AND K POLARIZATIONS. Toby A. Griner and Richard G. Olsen. Bioenvironmental Sciences Department, Naval Aerospace Medical Research Laboratory, Pensacola, FL 32508

To extend our knowledge in radio-frequency (RF) and microwave dosimetry, average SAR in a sitting rhesus model was obtained for three orthogonal orientations of irradiation near whole-body resonance (225 MHz), at a frequency of observed partial-body resonances (1290 MHz), and at a frequency more than 10 times above resonance (5.95 GHz). A 9 kg model, composed of muscle-equivalent material, was irradiated in anechoic chambers and whole-body absorbed RF energy was measured with a gradient-layer calorimeter. SAR measurements, in general, showed good agreement with published theoretical data based on prolate spheroidal models of nearly equal weight and height. Significant differences were found in some orientations, such as with E polarization at 1290 MHz, in which SAR was approximately twice that of the predicted value. These deviations were attributed to partial-body resonances in the limbs which coupled strongly to the incident electric field. Absorption rates for the H and K polarizations showed little deviation from the handbook values, presumably because the limbs could not strongly couple to the electric field for those orientations. It is concluded that theoretical methods in dosimetry are least applicable in the range of frequencies just above resonance where the arms, legs, and head may individually resonate.

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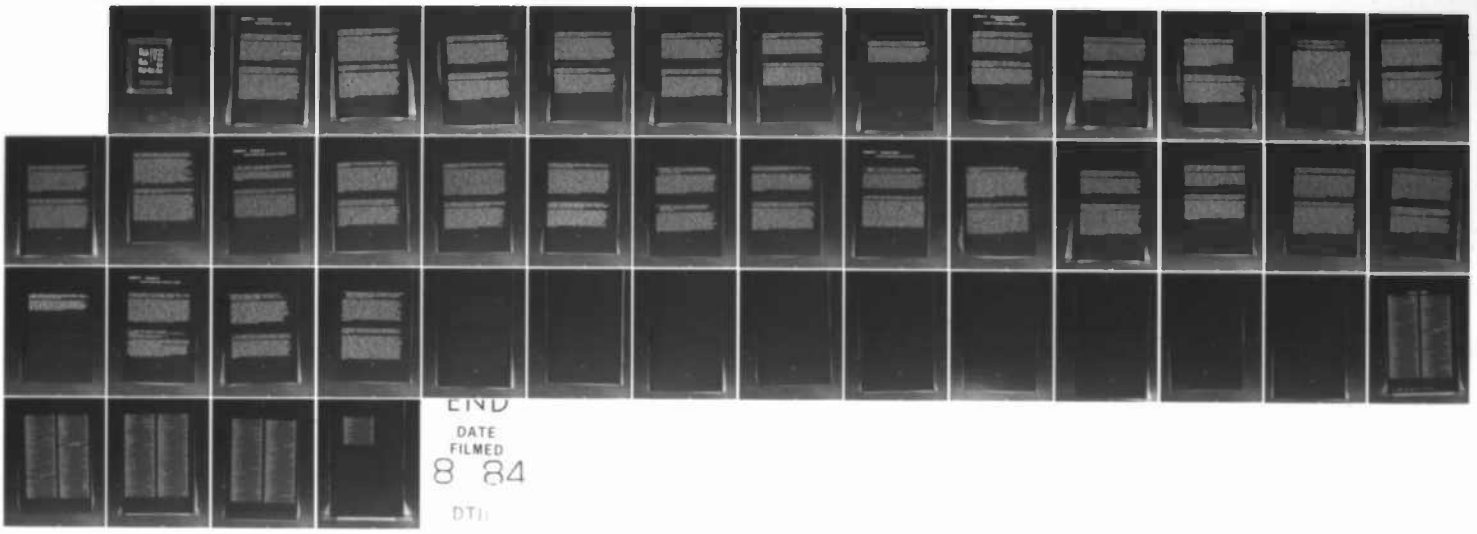

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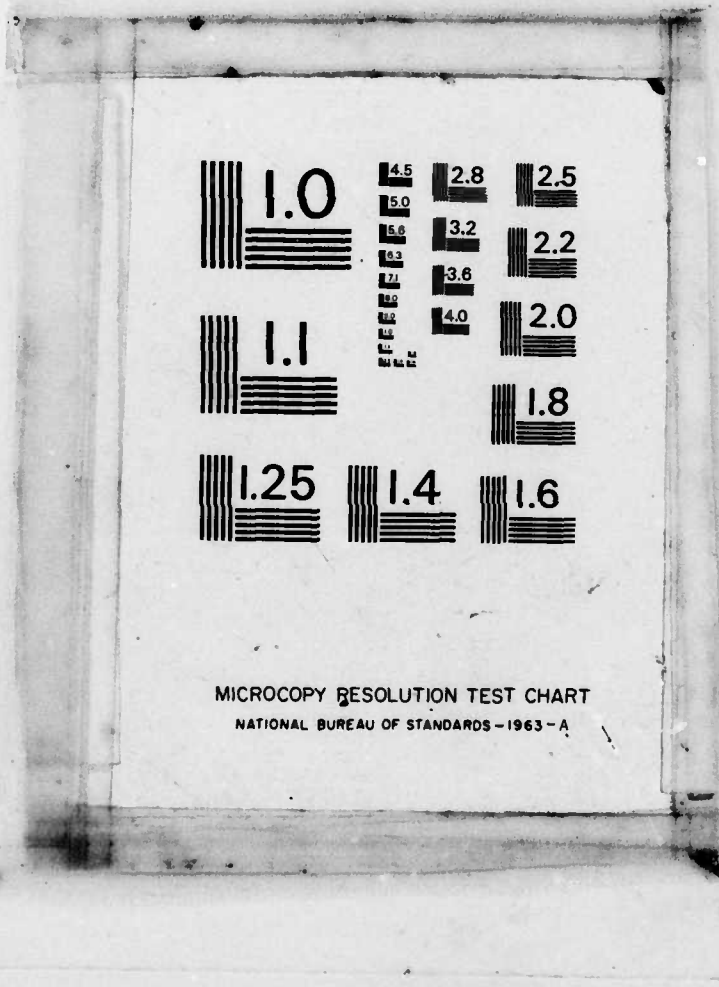
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SESSION L Dosimetry II

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L-5 AVERAGE SAR AND SAR DISTRIBUTION IN MAN EXPOSED TO 450 MHz RADIOFREQUENCY RADIATION. Arthur W. Guy and Chung-Kwang Chou. Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, WA 98195

The average SAR and SAR distribution on the body of man exposed to 1 mW/cm^2 plane wave 450 MHz radiation was measured for 12 possible field polarizations and 4 body postures (sitting with arms at the side and standing with arms at the side, arms raised above the head and one arm extended). The average SAR was obtained calorimetrically from scaled models of man (scale factor 5.44) composed of liquid synthetic tissue exposed to a frequency of 2450 MHz to simulate exposure of full size man to 450 MHz radiation. The SAR distribution was obtained from computer processed thermograms taken before and after exposure of gel phantom models. The mean SAR as averaged spatially for all postures and polarization was .0498 $\pm$ 0.0075 SD W/kg with a minimum value of .0365 W/kg and a maximum value of .0714 W/kg. The spatial peak SAR was a high as .2, .6, and .3 W/kg for the neck, wrist and ankles, respectively. The results indicate that the level of average SAR resulting from 450 MHz exposure is relatively independent of polarization and posture while the location and magnitude o the peak SAR may vary considerably.

L-6 SAR IN ADULTS AND CHILDREN IN AND NEAR VEHICLES DURING 835 MHz MOBILE RADIO TRANSMISSION. Arthur W. Guy, Chung-Kwang Chou, John McDougall* and Carroll Sorensen.* Bioelectromagnetics Research Laboratory, Department of Rehabilitation Medicine, University of Washington, Seattle, Washington 98195.

A study was made of the power density illuminating persons in and near a compact automobile during 835 MHz Mobile radio transmission from antennas mounted on the roof or rear fender. The resulting SAR in both adults and children were determined through measurements of SAR in full scale phantom models composed of muscle equivalent gell. Power density measurements were made with an NBS power density meter calibrated at 835 MHz and SAR distributions were determined by measurement of electrical fields with a diode probe sensor and measurement of temperature change by thermography and a Vitek thermister probe. Based on 1 watt power into the antenna power densities up to 630 $\mu W/cm^2$ were measured at closest typical human proximity to the antenna outside of the vehicle and between 8 to 44 $\mu W/cm^2$ in occupied regions within the vehicle. Maximum SAR levels were 310 mW/kg and 217 mW/kg for adults and children respectively outside of the vehicle and 29 mW/kg and 19 mW/kg for adults and children respectively inside the vehicle.

L-7 THE EFFECT OF FREQUENCY AND GROUNDING ON HUMAN WHOLE-BODY RF ABSORPTION IN E POLARIZATION. Douglas A. Hill. Radiation Biology Section, Defence Research Establishment Ottawa, Ottawa, Canada, K1A 0Z4.

The absorption rates of five male human volunteers have been measured from 3 to 41 MHz. The subjects are exposed to about 10 $\mu W \cdot cm^{-2}$ inside our very large (6.1 × 7.3 × 13.0 m) TEM cell. Both the EKH and EHK orientations were employed under both free-space and grounded conditions. Absorption rates for the EKH orientation exceed those of the EHK orientation by thirty percent in free space, but only by ten percent when grounded. The average measured absorption rates at 10 MHz exceed the average model calculations by a factor of three (for free space) or four (grounded). The grounded absorption rates vary with frequency (f) as $f^{2.0}$ from 3 to 25 MHz and then level off at the peak. The free-space absorption rates vary as $f^{1.6}$ from 3 to 18 MHz and as $f^{2.8}$ from 18 to 41 MHz. This increase in slope just below the free-space resonance is consistent with some calculations and Gandhi's measurements on saline-filled figurines. The average male, when exposed grounded in an EKH orientation to the maximum permitted exposure under the new ANSI standard, will absorb 0.55 ± 0.15 $W \cdot kg^{-1}$ over most of the 3 to 41 MHz frequency range. This just slightly exceeds the ANSI target of 0.40 $W \cdot kg^{-1}$.

L-8 THE EFFECT OF INCOMPLETE GROUNDING ON HUMAN WHOLE-BODY RF ABSORPTION IN E POLARIZATION. Douglas A. Hill. Radiation Biology Section, Defence Research Establishment Ottawa, Ottawa, Canada, K1A 0Z4.

The whole-body absorption rates of human volunteers exposed in E polarization have been measured with different dielectric spacers between the subject's feet and the ground plane. Little difference was found between the results for the EKH and EHK orientations. From 10 to 25 MHz, an air gap of 3 to 6 mm reduces the absorption rate to half the grounded rate. On the other hand, at 40.68 MHz, an ISM frequency near the grounded resonance, an air gap of 50 to 80 mm is required for the same effect. When a spacer with a dielectric constant (K) > 1 is used instead of air, the separation distance for the same reduction in absorption increases by a factor of K. This results from having the same capacitance between the feet and the ground plane. Typical leather-soled and rubber-soled footwear reduce the absorption rate to 30 to 60 percent of the grounded rate at the below-resonance frequencies. All of the above results are consistent with the theoretical predictions for either the cylinder or the block model of a human.

L-9 BETTER MODELS OF HUMAN RF ABSORPTION IN E POLARIZATION AT FREQUENCIES BELOW RESONANCE. Douglas A. Hill. Radiation Biology Section, Defence Research Establishment Ottawa, Ottawa, Canada, K1A 0Z4.

Measured human whole-body absorption rates in E polarization from 3 to 25 MHz are three to four times higher than most standard model calculations. For three simple models (ellipsoid, prolate spheroid and cylinder), the key variable affecting the absorption rate is shown to be the axial ratio, R = (length/diameter). For R > 5, the internal electric field in the three models is shown to be primarily the electrostatic field which can be calculated from the depolarizing factors published in the 1940s. Simple formulas for the quasi-static absorption rate of a cylinder or prolate spheroid under both free-space and grounded exposure conditions have recently been developed. The cylinder formulas were verified by TEM-cell measurements as a function of frequency and saline conductivity. For a model conductivity of 0.43 S/m (2/3 the wet-tissue value) the measured human RF absorption rates from 3 to 25 MHz, under both free-space and grounded conditions, can be fit by either an ellipsoidal model with R = 10.1 or a cylindrical model with R = 8.5.

L-10CALCULATION OF THE ELECTRIC FIELD IN A TEST TUBE CONTAINING CHICKEN BRAIN AND BUFFER SOLUTION. Henry S. Ho*, Daniel H. Schaubert**, and T. Whit Athey*. *NCDRH, FDA, Rockville, MD 20857. **Electrical Engineering Dept., U. of Mass., Amherst, MA 01003.

The moments method with tetrahedral elements was used to calculate the SAR and electric field distribution in a ellipsoidal model of chicken brain immersed in buffer solution contained in a test tube. The chicken brain model was an ellipsoid of dimensions .841 cm and .810 cm along the major and minor axis respectively. The volume was 0.3 ml. The buffer solution which surrounded the chicken brain had the shape of the bottom of a test tube, consisting of a 1.42 cm diameter hemisphere and a section of cylinder of the same diameter and .347 cm length. Total volume of the chicken brain in buffer solution was 1.3 ml. Plane-wave sources of frequencies 50, 147, 450, 915 and 2450 MHz were used for this calibration. The results indicate a large decrease in SAR and electric field in the chicken brain with decrease in frequency from 2450 MHz to 50 MHz. However, the ratio of peak to average electric field remains substantially the same at all frequencies. Hence for a given average SAR where an average temperature rise due to RF heating is unlikely, no "hot spots" are likely to cause a local temperature rise.

L-11 SPECIFIC ABSORPTION RATE DISTRIBUTION IN LIFE SIZED HUMAN PHANTOMS FILLED WITH TISSUE EQUIVALENT LIQUID. William D. Hurt, USAF School of Aerospace Medicine, Brooks AFB, TX 78235.

Current safety standards for exposure to radiofrequency radiation (RFR) are based on acceptable acute thermal burdens produced by the absorption of electromagnetic energy. Whole body average specific absorption rate (SAR) values can be calculated using models of man; however, there is concern over the distribution of the SAR in the body. Areas where the localized SAR is high could be harmful, even when the average SAR is not significant enough to cause any concern. Measurements have been made on two human size phantoms filled with tissue equivalent liquid, one containing skeletal features and the other without. The objective was to determine the effect that the bones have on the SAR distribution. Results of measurements made with Vitek temperature probes and implantable E-field probes will be presented.

L-12 FIELD MEASUREMENTS IN HUMAN MODELS EXPOSED TO 60-Hz ELECTRIC FIELDS. William T. Kaune and William C. Forsythe*. Pacific Northwest Laboratory, Richland, WA 99352

We report direct measurements of electric fields and current densities induced in grounded saline human models exposed to 60-Hz electric fields. For an exposure field of 10 kV/m, current densities in the chest are in the range 125-300 nA/cm^2, corresponding to average electric fields in the human chest of roughly 0.01-0.03 V/m. A strong horizontal current-density enhancement occurs in the axillae with peak values of about 400 nA/cm^2. The vertical current density in the arms, when held downward, is in the opposite direction to that in the chest. Current densities in the abdomen, pelvis, and legs are a strong function of whether the body is grounded through one or both feet. With one foot grounded, horizontal current densities in the lower pelvic region reach 770 nA/cm^2, which is the largest value ever measured by us in the human torso. A major use of these data will be in comparing animal and human exposure to 60-Hz electric fields.

L-13 UPPER BOUND ON GROUND-LEVEL SMALL-AIR-ION CONCENTRATIONS PRODUCED BY HVdc TRANSMISSION LINES. William T. Kaune, Murlin F. Gillis, and Richard J. Weigel. Biology Department, Pacific Northwest Laboratories, Richland, WA 99352.

Concerns have been raised that animals and humans in the vicinity of high-voltage direct-current (HVdc) transmission lines are exposed to air-ion concentrations significantly higher than normal atmospheric levels. Both experimental and theoretical studies have been made to document actual exposure levels. Unfortunately, the exact calculation of air-ion concentrations produced by HVdc lines is very difficult. In this paper we show theoretically that ground-level small-air-ion charge densities produced by bipolar HVdc transmission lines are bounded above by $\varepsilon_0 V/h^2$, where $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m, V is the line-to-ground voltage, and h is the line height. Comparison of measured data with this bound shows that it predicts, with good accuracy, maximum levels produced by actual HVdc transmission lines.

SESSION M Neurological/Physiological/ Behavioral Effects

Cochairs: Jose Delgado and Virginia Bruce-Wolfe

M-1 EFFECT OF IMPULSE MICROWAVE EXPOSURE ON FROG'S HEART RATE IN VITRO. K. C. Yee, Chung-Kwang Chou and Arthur William Guy. Bioelectromagnetics Research Laboretory, Depertment of Rehabilitation Medicine and Center for Bioengineering, University of Weshington, Seattle, WA 98195

Isolated frog heerts were pleced individually in a waveguide filled with Ringer's solution. 0.9% NeCl solution glass electrodes were placed in the ventricular muscle for recording of heertbeat. In group A, the preparetions were exposed for 30 minutes to 2450 MHz pulsed microwaves. The pulses were 10 μs in duretion, 10 ms epert end 50 pulses in a group. The exposure was triggered by each heartbeat and the average SAR during esch 500 ms exposure was 8.55 W/kg. Group B wes treated the same es group A except the exposure was not synchronized with the ECG. In group C, isolated hearts were exposed to a smaller amount of energy (2 W/kg). Group D served es a control. No statistically significant effects were found.

M-2 EFFECT OF MICROWAVE RADIATION ON THE CARDIAC POTENTIAL OF FROG. K. C. Yee, Chung-Kwang Chou and Arthur William Guy. Bioelectromagnetics Research Laboretory, Depertment of Rehabilitation Medicine end Center for Bioengineering, University of Weshington, Seettle, WA 98195

Frog ventricular muscle cells were exposed to 2450 MHz CW microweves in a tempereture-controlled liquid filled waveguide with input power set to correspond to an SAR of 8.55 W/kg. During exposure the muscle wes stimuleted at 0.3 Hz (normal frog heartbeat rate) or .003 Hz by a cerbon loaded Teflon electrode. The heart potential was recorded by e glass microelectrode filled with .9% NaCl solution. No changes were seen in the potential due to the microweve exposure when the temperature of the Ringer's solution surrounding the preperetion was controlled within .1° C. When the tempereture wes not controlled, however, the temperature rise in the liquid was 1° C at the end of the 30 minute exposure. This resulted in decreased duretion and increased half-time of the cell potential for the 0.3 Hz stimulation, but only decreased duretion for the .003 Hz stimulation.

M-3 EFFECTS OF CW AND LOW FREQUENCY AMPLITUDE MODULATED MICROWAVES ON THE CALCIUM EFFLUX FROM HEART TISSUE. Jean-Louis Schwartz* and Geoffrey A.R. Mealing*, Division of Biological Sciences, National Research Council, Ottawa, Ontario, Canada, K1A 0R6.

^{45}Ca efflux from electrically stimulated atrial strips of the frog heart (Rana Catesbeiana) exposed to electromagnetic radiation was studied using a continuous perfusion technique. After a 40 min loading period, the strips, still attached to the non-perturbing electrodes and the contraction transducer, were rinsed in non-radioactive Ringer and simultaneously exposed in a stripline apparatus to 1 GHz microwaves at incident power levels ranging from 5 μW to 2.5 W (SAR from 3.2 μW/kg to 1.6 W/kg). Waves were either constant or modulated at 0.5 Hz in synchrony with the stimulus, or at 16 Hz. Perfusate was collected every 2 min for 30 min and counted in a scintillation counter. No significant changes were detected in the ^{45}Ca efflux process. These results contradict other observations made in this laboratory on whole heart of the frog exposed to 240 MHz electromagnetic radiation in a similar power range and using identical modulation patterns.

M-4 **A SYSTEM FOR REGISTERING EVOKED KINETIC RESPONSES AND CHANGES IN RESPIRATION COINCIDENT WITH MICROWAVE EXPOSURE.** H. Wachtel, R. Jacobson, and G. Zartman. Department of Electrical Engineering, University of Colorado, Boulder, CO 80309.

In studying microwave effects on neural function or behavior it is highly desirable to maintain precise dosimetry while recording a well defined response pattern without invasion of the animal's body or distortion of the field. All of these objectives can be met by using a combined restraining and movement detector system that we have devised for our studies of wide microwave pulse effects on neural function. Using this system a mouse (or larger rodent) is confined, except for its tail, in a small polyethelene cage (fashioned from a large syringe). Any and all motions of the body, including respiratory movements, can then be registered by connecting the tail to a piezo-electric crystal mounted well outside the microwave field. We have been using this system specifically to measure kinetic responses directly evoked by microwave pulsing, but it can also be used to register kinetic patterns or respiratory rhythm changes in longer term, CW situations. The same basic system can also be used together with EKG recording electrodes, thermal probes or even implanted brain electrodes (high resistance type) in order to explore a wide variety of physiological responses simultaneously.
Supported by ONR Contract N0014-81-K-0387

M-5 **KINETIC RESPONSES EVOKED IN MICE EXPOSED TO WIDE MICROWAVE PULSES.** R. Jacobson, and H. Wachtel. Department of Electrical Engineering, University of Colorado, Boulder, CO 80309.

Our predictions regarding optimal pulse widths for eliciting neural modulation were further tested using the evoked kinetic response (EKR) technique described in the previous paper. For this purpose mice (HS strain) were exposed in a closed waveguide (2450 MHz, TE mode) to wide microwave pulses of known energy with intensity and duration varied reciprocally. Intervals between pulses were kept long enough (90 secs) to avoid thermal accumulation and the length of each experiment was limited to the 30 minutes prior to onset of constrain induced torpor. Three different protocol were used in this investigation. First an extended series of identical pulses were presented and EKRs measured. The variance of these responses was minimal. A second experiment presented sets of three equi-energy pulses varying in duration and magnitude. The EKR was averaged for each pulse duration group. Analysis of variance shows that the response varied as a function of pulse width ($p < .01$). In the third protocol, pulse duration, and magnitude combinations required to elicit EKR levels were measured and compared to the predictions of our model.
Supported by ONR Contract N0014-81-K-0387.

M-6 **KINETIC RESPONSES IN MICE SUPPOSEDLY KILLED INSTANTLY BY MICROWAVE BRAIN INACTIVATION.** H. Wachtel, W. B. Stavinoha, and A. T. Modak. Dept. of Electrical Engineering, University of Colorado, Boulder, CO 80309 and Department of Pharmacology, University of Texas, Health Sciences Center, San Antonio, TX 78284

The use of microwave heating to abruptly halt neural activity and inactivate certain enzymes (such as AChe) has become increasingly popular among neurochemists. It is generally assumed that the massive temperature changes (up to 40°C) produced in the brain occur rapidly enough (in less than 0.5 sec) to preclude any neural response that would alter the neurochemical state (released transmitter levels) of the brain. In order to test this assumption, we exposed mice to "brain inactivating" microwave doses (2450 MHz for 200 msec at an approximate brain S.A.R. of 500 W/gm) while recording their Evoked Kinetic Responses (EKR). Even though the mice succumbed fairly quickly to these lethal exposures, they invariably responded with a very intense EKR during, and shortly after, the exposure pulse. Furthermore, in several cases where a second or third dose followed the first, an appreciable EKR was still registered. These results along with the recordings of heart rate responses, indicate that these "brain inactivating" microwave doses probably lead to rather substantial neural activation prior to death.

M-7 POWER FREQUENCY ELECTROMAGNETIC FIELDS AFFECT THE NERVOUS SYSTEM
AN EXPERIMENTAL STUDY

Hans-Arne Hansson, Associated Professor, Institute of Neurobiology,
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Conflicting results have been presented with regard to the question whether power frequency electromagnetic fields affect the nervous system, partly reflecting variation in resolution and sensitivity of the methods used to analyse possible effects. We have used combinations of light- and electron microscopy, immunohistochemical, immunochemical and biochemical methods to study brain from animals. Rabbits exposed to 14 kV/m, 50 Hz, during their first postnatal weeks were demonstrated to get numerous lamellar bodies in their Purkinje nerve cells, as compared to controls kept in Faraday's cage or outside measurable E-field. The number of lamellar bodies varied, but with few exceptions the Purkinje nerve cells in the hemispheres and vermis regions of the cerebellum contained several hundred. Lamellar bodies were further observed in Purkinje cell dendritic spines, never observed in the controls. Cerebellar glial cells and the radiating Bergmann glial fibres, as studied by the distribution of the glial protein S-100, were demonstrated to become increased in number and size. The glial fibrillary acidic protein, present in fibrillary astrocytes, was used to demonstrate hyperplastic and hypertrophic changes mainly in the granular cell layer and white matter. Immunochemical and biochemical analyses revealed an increased amount of S-100 per protein unit and wet weight in the hemispheres of the cerebellum in exposed rabbits as compared to control, reflecting gliotic reactions. Similar changes could be demonstrated also in other parts of the central nervous system.

Studies have been performed on mice, rats and guinea pigs, exposed according to various schedules. It was noticed that there are species differences with regard to induced changes. The significance as well as the question of reversibility of described changes will be discussed.

M-8 NON INVASIVE MAGNETIC STIMULATION OF THE MONKEY CEREBELLUM. José M.R. Delgado, José L. Monteagudo, and Eduardo Ramírez. Centro "Ramón y Cajal," Madrid 34, Spain.

Experiments were performed in awake monkeys equipped with permanently implanted electrodes located in motor areas and limbic system. The animals were restrained in Brady chairs. Spontaneous mobility and EEG were recorded. Minimal motor thresholds (for example, flexion of the right hand with 120 uA) were determined with the usual electrical stimulation parameters (cathodal, 100 Hz, 0.5 msec pulse duration). Then magnetic fields were applied over the cerebellum using coils strapped to a helmet or implanted subcutaneously over the posterior part of the skull. The coils were flat spirals of 12 turns, with 13 mm external diameter, 0.05 ohms resistance, auto-inductance of 4 UH activated by a square wave generator which, with 1.0 Amp intensity, produced a measured magnetic field of 1 Gauss to a depth of 10 mm. Results showed that application of pulsed magnetic fields with 9 to 500 Hz produced significant modification of local motor excitability, outlasting the presence of the magnetic field for minutes or hours. In addition, reduction of spontaneous motility, relaxation, and sleepiness appeared following application of fields of 50 Hz, while restlessness and attempts to escape were produced with fields of 100 Hz. These effects were reliable on different days.

M-9 OBSERVATIONS ON THE FINE STRUCTURE OF HIPPOCAMPUS AND AMYGDALOID COMPLEX IN NEONATAL RATS EXPOSED TO 2.45 GH2 (CW) MICROWAVE IRRADIATION. M.F. Sherif, E.N. Albert and N.A. Boraie*. Department of Anatomy, Kuwait University, Faculty of Medicine, Kuwait and The George Washington University, Medical Center, Washington D.C.

Six-day old rats were exposed in the far field to 2.45 GHz (CW) microwaves at 10 mW/cm^2 for 5 consecutive days, 7 hours per day (SAR 2W/Kg). Pups were euthenized one day after exposure and the brains processed for electron microscopy. Matching areas from the hippocampal formation and amygdaloid nuclear groups at corresponding coronal planes were examined in both irradiated and sham irradiated animals. The preliminary results indicated disorderly arrays of the rough endoplasmic reticulum (RER) of some pyramidal cells of the hippocampus in the irradiated animals. Short isolated cisternae delimitting broad fields of the cytoplasm heavily filled with free ribosomes and polysomal clusters, were observed in some pyramidal cells, some neurons of the stratum oriens and the amygdaloid nucleus. Some cisternae were markedly dilated specially at the sites of their branching. However the RER of the amygdaloid neurons in the experimental animals did not show observable change in its pattern. Such picture is not indicative of definite chromatolysis. Nevertheless, the overall appearance may reflect a change in the functional activity of the limbic system.

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M-10 INDUCTION OF NON-INVASIVE SPINAL CORD INJURY IN RATS WITH LOCALIZED MICROWAVE IRRADIATION. Pava Popovic and Carl H. Sutton. Dept. Physiology, Emory Univ., Atlanta, Ga. and Dept. Surgery, Univ. South Florida, Tampa, Fl.

Therapy for recovery in severe spinal cord (SC) injury is not established. Until now use of different experimental models to induce the SC injury gave inconclusive results. A new approach proposed here, experimental induction of SC injury with microwave heating, might offer a reproducible and reliable animal model to study this problem. The non-invasive microwave-induced SC injury can be localized to any segment of the cord without extensive surgery. The SC injury can be fully controlled, quantitated, and graded on the basis of measured amount of energy applied to the SC site. In this work lumbar area (L 4, 5, 6) in eight rats was exposed to microwave irradiation (2450 MHz) and heated to 43°C. Adjoining muscle temperature was kept at 43°C (thermocouple monitoring). The one hour long irradiation induced permanent paraplegia in the rats. The same intensity of microwave irradiation (43°C) lasting 30 minutes induced only temporary changes without paraplegia. Localized microwave irradiation seems to provide new possibilities to study SC experimental injury.

M-11 THERMAL EFFECTS OF RESONANT RF RADIATION IN SQUIRREL MONKEYS LOCATED OVER A GROUND PLANE. Ronald J. Spiegel and Thomas R. Ward, Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711

Previous studies have been concerned with the autonomic thermoregulatory response of the squirrel monkey when exposed to RF radiation. These studies, however, have been performed at only one frequency: 2450 MHz. Similar research must be performed at other frequencies, especially at whole-body resonance, because RF energy is absorbed by biological objects in an extremely nonuniform fashion and consequently the thermoregulatory response of the monkey might be significantly different. To simulate a realistic situation of a human standing on the ground, squirrel monkeys were resonantly irradiated in a ground-plane anechoic chamber with their feet in good contact with the ground plane. The exposure frequency was 350 MHz, and the relative humidity and temperature inside the chamber were controlled within around 0.5% of preset values. The chamber air velocity in the vicinity of where the monkeys were placed was measured at less than 0.075 m/s; i.e., essentially "still" air conditions existed. Experimental data will be presented on the whole-body SAR thresholds to initiate cutaneous vasodilation of the tail and feet, sweating from the feet, and adjustments in metabolic heat production. These thresholds were determined as a function of ambient air temperature, where the air temperatures ranged from 20 to 35°C.

M-12MINIMAL INCREASES IN HYPOTHALAMIC TEMPERATURE ACCOMPANY MICROWAVE-INDUCED CHANGES IN THERMOREGULATORY BEHAVIOR. Eleanor R. Adair, Barbara W. Adams*, and Gillian M. Akel*. John B. Pierce Foundation Laboratory, New Haven, CT 06519.

Three adult male squirrel monkeys (Saimiri sciureus), trained to regulate environmental temperature (T_a) behaviorally, were chronically implanted with teflon re-entrant tubes in the medial preoptic/anterior hypothalamic area (PO/AH). A Vitek probe inserted into the tube measured PO/AH temperature continuously while changes in thermoregulatory behavior were induced by either brief (10-min) or prolonged (2.5 hr) unilateral exposure to planewave 2450 MHz CW microwaves (E polarization). Power densities explored ranged from 4 to 20 mW/cm^2 (SAR=0.15[W/kg]/[mW/cm^2]). Rectal temperature and four representative skin temperatures were also monitored, as was the T_a selected by the animal. When the microwave field was intense enough to stimulate a monkey to select a cooler T_a (8 mW/cm^2 and above), PO/AH temperature rose ~0.3 °C but seldom more. Lower power densities provoked smaller PO/AH temperature increases and no change in thermoregulatory behavior. Rectal temperature remained constant and PO/AH temperature rose only 0.2-0.3 °C during 2.5 hr exposure at 20 mW/cm^2 because a T_a 3 °C cooler than normal was selected. However, greater PO/AH temperature increases than 0.3 °C were sometimes recorded, but only when behavioral thermoregulation failed. (Supported by USAF Contract F-33615-82-K-0600).

M-13ALTERED THERMOREGULATORY RESPONSES IN IMMATURE RATS FOLLOWING REPEATED EXPOSURE TO 2450 MHz MICROWAVES. Donald E. Spiers* and Eleanor R. Adair. John B. Pierce Foundation Laboratory, New Haven, CT 06519.

Eight rats, in groups of four, were either sham-exposed or exposed in an anechoic chamber to planewave 2450 MHz CW microwaves (K polarization) at a power density of 5 mW/cm^2. Each rat was partially restrained in a plastic mesh cylinder and located approximately one wavelength from littermates during the exposure period. All exposures were conducted at an environmental temperature (T_a) of 30°C from 1700 to 2000 hrs, beginning at 6-7 days of age and continuing for 10 days. Thermoregulatory profiles were determined for animals, one day before and one day after the exposure period, by measuring responses to four set environmental temperatures (range = 25-35°C). Thermogenic and thermolytic abilities were assessed from measurements of steady-state oxygen consumption and both colonic and tail-skin temperatures. Groups exhibited no significant differences in thermal responses before the exposure period. Likewise, growth and development of both groups were similar. Tail-skin temperatures of sham-exposed animals were slightly below those of microwave-exposed animals at T_a 30 and 32.5°C. Metabolic heat production and colonic temperature in microwave-exposed animals were significantly elevated above values noted in sham-exposed animals at T_a 30°C, with no differences observed at other environmental temperatures. These results suggest that sham-exposed animals had experienced adaptation to a mild cold stress and that such a change was reduced in microwave-exposed animals.

SESSION N Dosimetry III

***Cochairs:* Ronald Spiegel and Stanley V. Marshall**

N-1 INTERNAL DOSIMETRY OF A HETEROGENOUS SQUIRREL MONKEY PHANTOM MODEL EXPOSED TO 2450 MHz. James B. Kinn, Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711

Realistic aquirrel monkey phantom models incorporating internal bone structure and tissue types were constructed using molds from a living animal, to determine the whole body SAR and analyze the localized doaimetry. The phantoms were exposed to 2450 MHz in an anechoic chamber. Whole body SAR measurementa were made using a calorimetric technique and localized SAR was analyzed using temperature probes and thermography.

N-2 THEORETICAL AND EXPERIMENTAL EVALUATION OF THE AVERAGE SARs AT AND BEYOND RESONANCE. A. Lakhtakia*, M. F. Iskander*, and C. H. Durney. Department of Electrical Engineering, University of Utah, Salt Lake City, UT 84112.

With the development of the iterative extended boundary condition method (IEBCM) to solve for the scattering and the absorption characteristics of elongated, non-spherical lossy dielectric objects for the first time at and beyond the resonance frequencies, and with the introduction of the novel idea of using mixed basis functions for field representation inside composite bodies, it is now possible to compute the average SAR in highly elongated, homogeneous models of humans and animals in the post-resonance frequency range. Post-resonance SAR calculations made using the IEBCM have also been experimentally verified by measuring the average SARs in scaled phantoms exposed to the radiation fields of a horn antenna at 2450 MHz frequency. In particular, scale factors for the prolate spheroidal and capped cylindrical models of an average man and a sitting rhesus monkey were chosen to simulate the exposure of the real-size objects in the post-resonance frequency range. Numerical results illustrating the close agreement between the theoretical and the experimental evaluation of the average SARs will be presented; and the special features of the IEBCM as well as of the experimental procedure will be highlighted.

N-3 THERMAL MODELLING OF CELL EXPOSURE TO MICROWAVE RADIATION: TRANSMEMBRANE THERMAL GRADIENTS. J. A. Liburdy*, Mechanical Engineering, Dept., Clemson University, Clemson, SC 29631.

The question of the thermal environment of a modelled cell subjected to continuous and pulsed deposition of microwave radiation is addressed. Small temperature gradients across the cell membrane may cause local lipid phase changes (Liburdy, R. P., BEMS Meeting, 1982, LA, CA). The magnitude of these gradient is determined for continuous, instantaneous and periodic energy absorption. The thermal model considers a spherical cell geometry with a thin membrane layer. A parametric analysis is presented, with a range of specific absorption rates, to indicate the relative effect of variations of thermal properties on the temperature gradient across the membrane. Emphasis is on the influence of variation in membrane composition, such as lipid/protein structure, which will alter the thermal properties. However, in this case a homogeneous membrane is assumed. The model accounts for the transient response due to localized energy deposition and indicates the distinction between continuous and pulsed wave irradiation. Although indications are that transmembrane temperature differences may be small under steady state conditions significant differences can exist for short time intervals. Due to the thinness of the membrane, even small temperature differences result in large gradients which may be physiologically significant.

N-4 EFFECTS OF POWER-FREQUENCY ELECTRIC FIELDS ON IMPLANTED CARDIAC PACEMAKERS. J.C. Male* and D.G. Barton*, CEGB Central Electricity Research Laboratories, Leatherhead, Surrey, UK and G.S. Butrous*, S.J. Meldrum* and A.J. Camm*, Depts. of Cardiology and Medical Electronics, St. Bartholomew's Hospital, London EC1, UK.

Thirty-five patients fitted with 16 different pacemaker models (from 6 manufacturers) were exposed to 50 Hz electric fields up to a maximum of 20 kV/m. Four different response patterns were encountered: (1) normal sensing and pacing; (2) reversion to the fixed (interference) rate; (3) slow and irregular pacing; (4) mixed behaviour over a critical range of field strengths in which slow and irregular pacing preceded reversion to fixed-rate. The field strengths required to induce such behaviour varied from unit to unit and from model to model but in only two cases were they less than 5 kV/m. In general, the interference threshold depended on the magnitude and distribution of induced body current relative to the pacemaker as well as on field strength and thus varied with patient height, build and posture. While only a small proportion of pacemaker patients are likely to encounter electric fields strong enough to interfere with pacemaker behaviour, this possible hazard should be recognized.

N-5 THE SHAPE FACTOR INFLUENCE ON THE COUPLING OF ELF ELECTRIC FIELDS TO DIELECTRIC OR CONDUCTING BODIES. S. V. Marshall, Southwest Research Institute, P. O. Drawer 28510, San Antonio, TX 78284.

We show that coupling of a homogeneous biological body to an alternating electric field, as measured by the current induced in that body, is an inverse function of its shape factor, or depolarizing factor, and is essentially independent of its conductivity. This depolarizing factor L has an exact analytical expression for spheroids; for example, it is 1/3 for a sphere. Quantitative calculations of median cross section current in a circular cylinder are made using an empirical formula believed to be accurate to within 15% for ℓ/d (length to diameter) ranging from 0 to 1000. The formula may be adapted for square cross sections and applied for fields parallel to or normal to the cylinder axis. A cylinder having an ℓ/d of 10 couples 20 times as strongly to a parallel electric field as a sphere i.e., where a factor of 3 is used for a sphere, the expression $1 + 3\,\ell/d + 0.27\,(\ell/d)^2$ is used for the cylinder. The short circuit current to ground for a vertical cylinder in a vertical electric field is proportional to $1 + 6\,\ell/d + 1.08\,(\ell/d)^2$. This can represent a human standing beneath a HV power line. A grounded hemi-prolate spheroid model is also used to calculate the current in various parts of the human body and found to be in good agreement with two other methods. The field enhancement normal to the body is inversely proportional to L, i.e., the maximum field normal to an isolated sphere is three times the applied field. (This work is related to DOE Contract DE-AC02-80RA50219).

N-6 ELECTROMAGNETIC FIELDS INDUCED IN SELECTED BOUNDED REGIONS BY HELMHOLTZ AIDING COILS. Bruce R. McLeod* and Reed Parker*. Department of Electrical Engineering and Computer Science, Montana State University, Bozeman, MT 59717

In previous work we developed closed form solutions for Maxwell's equations for two commonly used in-vitro experimental situations. These results emphasized the fact that the induced fields in the exposure region inside the boundaries are not uniform. Thus, knowledge of the spatial distribution of the induced fields could help explain some variation in experimental data especially when the boundaries are changed (for instance, going to an in-vivo situation). This paper will present the results of expanding the investigation to allow solutions to be found for much more general boundaries. We have developed a computer routine that first calculates the magnetic fields developed by the Helmholtz coils along a given set of boundaries. A second program then fits a solution to Maxwell's equations and the above boundary values. The results are presented both numerically and in three dimensional and two dimensional plots. Data on a computer model for a fractured leg show several interesting features including hot spots and minima in the area of the break and along the leg bone.

N-7 RESPONSE OF E-FIELD PROBE IN THE PROXIMITY OF HUMAN BODY. Devendra Misra and K.M. Chen, Department of Electrical Engineering and Systems Science, Michigan State University, East Lansing, MI 48824

An E-field probe is often carried by a man on his body surface to sensor the intensity of the EM field he is exposed to. The response of the probe is found to depend on the location of the probe on the body surface with respect to the direction and polarization of the incident EM wave and also on the probe-body coupling. Thus, the reading of the probe is not a simple indication of the intensity of the incident EM wave. We consider a geometry of an E-field probe, a short dipole receiving antenna, located on the surface of human body, simulated by a long lossy dielectric cylinder, being illuminated by an incident EM wave of TE or TM polarization. The EM fields near the body surface are determined first. The induced voltage on the probe, oriented in various directions with respect to the body surface, is then determined by taking into account of the probe-body coupling. The probes consisting of a single dipole and three orthogonal dipoles are both considered. The response of the probe is determined as a function of its location on the body surface with respect to the direction of the incident EM wave. The shadowing effect due to the body is found to be very significant. Experiments were also conducted to measure the probe respone in the presence of a cylindrical column of saline water. A good agreement between theory and experiment was obtained.

N-8 MODELLING OF UNECHOID CHAMBER EXPOSURE CONDITIONS AND ASSESSMENT OF THE ASORBED ENERGY AT BIOLOGO-HYGIENIC INVESTIGATIONS. M.I.Rudnev, V.V.Varetsky, L.Galich, V.N.Dyachenko. Kiev A.N.Marzeev Scientific Research Institute of General and Communal Hygiene, Popudrenko 50, Kiev - 252160, USSR

In connection with growing demands as to standard setting accuracy, demands to quality of experimental studies and, first of all, to precise knowledge and control of a number of parameters complex, characterizing exposure conditions, are also growing. To settle this task the most optimal unechoid chamber exposure conditions in the plane wave field zone are chosen. An investigating biologic effects of week factor manifestation, peculiar to communal hygiene, of importance is creation of optimal environmental parameters inside the chamber for the given animal species and supporting them during the whole experiment taking into account the fact that chronic experiments may be measured during lots of months. For this purpose a system on the basis of conditioners BK - 1500 and air-stoves was set-up. Questions on identification of the energy absorbed by rat corpses are considered in the report.

N-9 VISUALIZATION OF ELF ELECTRIC FIELD DISTRIBUTION AROUND ANIMAL BODY : (1) CALCULATION, Koichi Shimizu, Tetsuo Kobayashi*, Hidemasa Sekimizu* and Goro Matsumoto, Research Institute of Applied Electricity, Hokkaido University, Sapporo, 060 Japan.

We have developed two techniques which visualize the ELF electric field around animal body. The one is the numerical calculation based on the finite difference method. The process of this technique is highly automated to divert the photographs of a free-moving animal to the boundary conditions for the field calculation. The field distribution is presented in the patterns of equipotential lines, and the surface electric field of the animal body is presented in vector patterns on its surface. It is shown quantitatively that the electric field on the animal body (e.g. nose, back, ears) changes considerably as the animal changes its posture. Applying this technique to the motion picture of a moving mouse, we can see an interesting behavior of the field distribution around the mouse in motion. In addition, the body current due to the motion in a DC electric field can be obtained for the specific parts of the body. This technique is widely applicable to the objects with any shapes including a human.

N-10 VISUALIZATION OF ELF ELECTRIC FIELD DISTRIBUTION AROUND ANIMAL BODY : (2) MEASUREMENT, Koichi Shimizu, Hideto Endo* and Goro Matsumoto, Research Institute of Applied Electricity, Hokkaido University, Sapporo, 060 Japan.

The ELF electric field distribution around a human model was visualized in a color-graphic pattern using a microcomputer-controlled measurement system. To minimize the field perturbation due to the measuring devices, an optical field meter was used. The meter consists of a small dielectric sensor (1 x 1 x 2 cm), optical fibers and data-processing electronics. Metallic objects including the electronics part of the meter were kept away to prevent them interacting with the field to be measured. The field distributions around a human model were obtained with various postures and conditions. They include ; the postures upright and on all fours, with and without insulating shoes, with the arm up and down, etc. With the calculation technique, this provides us better understanding on the location and the extent of the field concentration on our body. They will also enable us to evaluate the dose of the electric field exposure on experimental animals and humans in their practical activities.

N-11 DOSIMETRY FOR CALCIUM-ION EFFLUX EXPERIMENTS BY NUMERICAL METHODS. Ronald J. Spiegel and William T. Joines, Health Effects Research Laboratory, US Environmental Protection Agency, Research Triangle Park, NC 27711

The exposure geometry used in the RF irradiation of chick brain halves for calcium-ion efflux experiments was modeled using numerical procedures. The chick brain, immersed in a buffer medium, was approximated by a large number of small cubical blocks that were arranged to best fit the physical geometry, and the absorption rate density within each block was calculated by a numerical moment-method solution. The incident electric field distribution inside the TEM cell exposure system was also determined by numerical means. It was found that scaling ratios which predict carrier frequency dependence for RF induced calcium-ion efflux in actual experiments agree only for the bottom half of the brain as it sits in the test tube. This result suggests that the half of the brain located in the bottom of the tube, which is covered only by a very thin layer of buffer solution, may be the active site of calcium-ion efflux.

N-13 COMPUTER-CONTROLLED EXPERIMENTAL SYSTEM FOR ELECTROMAGNETIC DOSIMETRY. Stanislaw S. Stuchly, Mariuaz Barski, Benjamin Tam, George Hartsgrove and Stephen Symons, Dept. of Electrical Engineering, University of Ottawa, Ontario, K1N 6N5.

Experimental electromagnetic dosimetry is related to the studies of the physico-engineering aspecta of the interaction between radio and microwave radiations and biological systems. Specifically, it concerns the determination of the distribution of the internal electric field intensity in a phantom model of the human body exposed in the near-field of radio and microwave radiators. This objective is achieved using a computer-based scanning aystem capable of acquiring, storing, displaying, and recording the electric field intensity and ita direction. Non-perturbing miniature implantable triaxial probes are used for measuring the electric field. The ability to determine the distribution of the internal electric field intensity in a phantom model of the human body exposed in the field of electromagnetic radiators under computer control coupled with a good record-keeping procedure for the storage of large quantities of data and with modern display and recording facilities make this system a powerful research tool. A description is given of the hardware and software components of the scanning system and the results of experimental evaluation of the performance of the system.

SESSION O Behavioral Effects

Cochairs: Dennis Hjeresen and Sander Stern

O-1 DETECTION OF DC ELECTRIC DIPOLE FIELDS BY NURSE SHARKS (GINGLYMOSTOMA CIRRATUM). C. S. Johnson*, B. L. Scronce*, and M. W. McManus*. Biosciences Department, Naval Ocean Systems Center, San Diego, CA 92152.

Sharks can find food and other objects by detecting the electric fields associated with them. In order to study the effects of background electric fields on electrical detection, nurse sharks were trained to detect steel balls of four different diameters using the galvanic fields produced by the balls in sea water. Detection ranges increased with ball diameter from 5 cm for a .26 cm diameter ball to 30 cm for a 1.9 cm diameter ball. When a uniform background field was applied across the experimental tank detection ranges increased by approximately a factor of two in all cases providing the field was above the shark's detection threshold (5×10^{-9} v/cm). The reasons for this increase in detection range is not presently understood. The experiment is being repeated using DC electric dipoles produced by electrodes.

O-2 OPERANT BEHAVIOR OF RATS IS SIMILARLY MODIFIED BY CW AND BY PM MICROWAVE RADIATION. Robert M. Lebovitz, Ph.D. Dept. Physiology, UTHSCD, Dallas, Tx. 75235

Long-Evans rats were trained to stable performance on a multicomponent (fixed-ratio, timeout) operant task. Subgroups were thereafter exposed to microwave radiation (MWR) with a variety of modulation profiles, including continuous wave (CW) and pulse modulated (PM). Exposure (actual or sham) took place during daily three-hour behavioral sessions, and rates of responding were noted throughout. At moderately high MWR dose rates, CW and PM MWR (5.8 and 6.7 mW/g, respectively) similarly reduced the response rates during both components of the operant sessions. At 3.6 mW/g, whereas fixed-ratio responding was unchanged, timeout responding was reduced significantly. Again, CW and PM MWR yielded essentially equivalent results. At 1.5 mW/g, neither CW nor PM MWR influenced bulk operant behavior. The net change in whole-body temperature after one to three hours of exposure to MWR at these dose rates was determined. At 6 mW/g the elevation in body temperature ranged from 0.5 to 1.0°C; 3.5 mW/g was observed to have no effect. In summary: (1) fixed-ratio responding of rats for food was more robust, that is, less subject to suppression by concurrent exposure to MWR than was bar-pressing during timeout, (2) PM and CW MWR effectively enhanced stimulus control over timeout responding and (3) the equivalence of the effects of CW and PM MWR supported the hypothesis of a thermal basis for the effect despite the inability to necessarily detect changes in whole body temperature.

O-3 MOTIVATIONAL ASPECT OF ELECTRIC-FIELD AVOIDANCE IN RATS. J.A. Creim, D.I. Hilton, R.H. Lovely and R.D. Phillips, Pacific Northwest Laboratory, Richland, WA 99352

Rats, given the choice, spend more time shielded from a 60-Hz electric field than in the field at intensities $\geq$ 75 kV/m. The motivational aspect of this behavior was investigated. We placed a preferred food (.15% saccharin-flavored chow) on the exposed end and regular chow on the shielded end of a two-compartment shuttlebox. Water was available at both ends. Each of 36 rats was individually tested over a 7-day period. Each rat was adapted to the shuttlebox and food choice for 4 days, then a 23-hr baseline of shuttlebox side preference and intake of each food was measured with the electrode unenergized. The next day, 18 rats were tested for 23 hrs on an unenergized electrode, and the other 18 were tested with the electrode energized to produce a field strength of 100 kV/m. Saccharin-flavored food consumed by both groups during adaptation and baseline sessions, and by the controls (0 kV/m) was relatively constant (69% - 75% of total food consumption), whereas saccharin preference by exposed rats (100 kV/m) fell to 39% of total food intake. There was a concomitant reduction in the time exposed rats spent on the exposed side. Exposed rats showed a return to normal preference for saccharin-flavored food the next day. Electric fields of 100 kV/m are sufficiently adversive to disrupt established preference behavior for saccharin-flavored food by the rat. (Work performed under DOE Contract DE-AC06-76RLO-1830.

O-4 INTERACTION OF ELECTROMAGNETIC RADIATION AND DRUGS ON SCHEDULE CONTROLLED BEHAVIOR IN RATS. Michael I. Gage.* US Environmental Protection Agency, HERL, MD-74B, Research Triangle Park, NC 27711

If microwaves alter the receptivity of the brain to substances that normally do not cross the blood-brain barrier, the reported interactive effect of d-amphetamine and microwaves on operant behavior should also be seen with phenylpropanolamine, a congener of d-amphetamine considered to have minimal central nervous system effects. Forty male Sprague-Dawley rats were trained to headpoke using food as a reinforcer on a multiple random ratio 40, stochastic reinforcement of waiting 60 s (in which reinforcement probability increased as interresponse time lengthened) schedule. They were injected i.p. with 0, 0.75, 1.50, and 3.0 mg/kg of d-amphetamine sulfate, and 0, 3.75, 7.5, and 15 mg/kg of phenylpropanolamine HCl just prior to 30 min exposures to 0, 1 (0.2 W/kg estimated SAR), or 5 mW/cm^2 at 2450 MHz, CW, and tested just after these exposures. Different groups of four rats were exposed to each of the microwave power densities but all rats received all dosages of both drugs. The higher dosages of both drugs reduced response rates on both schedules. Microwaves in all but one condition had no effect on responding. There was no interactive effect of either drug with microwaves on response rates on either schedule. Under the conditions of exposure and testing in this experiment, continuous wave microwaves did not enhance drug effects on behavior.

O-5 BEHAVIORAL DETECTION OF 60-HZ ELECTRIC FIELDS BY RATS. Sander Stern, Victor G. Laties†, Charles Stancampiano†, Christopher Cox† and John O. deLorge. Department of Radiation Biology and Biophysics, School of Medicine and Dentistry, University of Rochester, Rochester, NY 14642

Food deprived rats were trained individually to press a lever in the presence of a vertical 60-Hz electric field but not in its absence. Such correct detections that occurred during the brief, 3 or 4 sec trials occasionally produced a food pellet. The probability of detecting the field increased as field strength increased. A logit transformation provided a good description of the data. The analysis showed that different rats could detect the field occasionally between 1 kV/m and 4 kV/m, more reliably between 4 kV/m and 10 kV/m, and almost always as the strength approached 20 kV/m. These performances occurred reliably in 19 rats with some studied for about 2 years. These results suggest that most other reported effects of 60-Hz electric fields on intact animals, if confirmed, may depend on detection of the field.

O-6 EFFECTS OF PRENATAL EXPOSURE TO 60-Hz ELECTRIC FIELDS ON OPEN FIELD AND MAZE PERFORMANCE OF F-2 GENERATION HANFORD MINIATURE SWINE. Richard H. Lovely, Jeffrey A. Creim and Richard D. Phillips. Biology & Chemistry Department, Battelle, Pacific Northwest Laboratories, Richland, WA 99352

In a multiple generation study that exposed or sham-exposed Hanford Miniature Swine (HMS) to a 60-Hz electric field (30 kV/m), male and female F-2 progeny were tested in two behavioral tasks. In the first task, HMS were tested at 1, 3 and 5 weeks of age for 15 min. in an open field. The latency to leave the center square, number of squares entered, amount of vocalization as well as number of defecations and urinations were determined. The only significant difference was that exposed females vocalized less than their sham-exposed counterparts, both within test sessions and over all three tests. F-2 progeny were also tested in a multiple unit T-maze st 8, 12 and 16 weeks of age. The HMS were trained for food reward with the food being placed in a different location for each test. Test sessions lasted 30 min. or until a criterion of 3 consecutive errorless trials had been reached. Latency to leave the start box, goal time, numbers of errors, total trials/session, defecations and urinations all failed to differentiate HMS with regard to treatment conditions. The significant difference in open field vocalizations as well as other behavioral observations did suggest that exposed female HMS were different from other groups in terms of emotionality and/or arousal level. (Research supported by the Electric Power Research Institute).

O-7 DIFFERENTIAL BEHAVIORAL EFFECTS IN THE RAT AS A FUNCTION OF MICROWAVE INDUCED TAIL HEATING: COMPARISON OF THREE RADIATION FREQUENCIES. R. Y. Emmerson*, J. A. D'Andrea, J. R. DeWitt*. Departments of Electrical Engineering, Bioengineering, and Psychology, University of Utah, Salt Lake City, Utah 84112.

Recent findings indicate frequency and orientation specific hotspots in tails of rats exposed to microwave radiation. The magnitude of the SAR differential between tail and the whole-body average ranges through factors of 50 at 360 mHz to 20 at 2450 MHz and 2 at 700 MHz. The possibility that differential tail heating may have behavioral consequences was investigated in an experiment utilizing a wheel turn as the operant. Comparisons of response rate were made for these three frequencies of radiation at whole-body average SAR's of 2 W/kg, 6 W/kg, and 10 W/kg. Fewer minutes of radiation were required to suppress response rate to 33 percent of baseline at the lower SAR's for both 360 MHz and 2450 MHz.

O-8 SLEEP-WAKE STATES IN CATS EXPOSED TO COMBINED CLICK, LIGHT FLASH AND PULSED RF FIELDS. W.R. Adey and H.J. Sukenik*. VA Medical Center and Departments of Physiology and Surgery, Loma Linda University School of Medicine, Loma Linda, CA 92357.

We have tested the Soviet LIDA instrument on sleep-wake states in chronic cats. This clinical device delivers 0.3 sec RF pulses at 40 MHz and PRFs of 10-100/min. Clicks, flashes and pulsed heat may be delivered concurrently as a "monotonous influence". A US patent also claims efficacy in "neuropsychic and somatic disorders". EEG and EKG data were recorded through high impedance connecting leads (*1.0 megohm* distributed resistance). Respiration was measured from CO_2 in expired air by infrared absorption. A 3-dimensional field plot with BRH and Narda probes showed a maximum incident intensity of 20 mW/cm^2 in the recommended therapeutic configuration. Preliminary data analysis suggests that the RF field alone for 30 min exerted only minor effects on sleep cycles, but that combined RF and light flash may elicit increased duration and depth of sleep (stages 3 and 4), with prolonged sleep after termination of exposure by comparison with control sessions. (Supported by US Navy Contract - # N60921-82-M-5960).

O-9 BEHAVIORAL EFFECTS OF PROLONGED EXPOSURE TO .5 mW/cm^2, 2450 MHz MICROWAVES. J. R. DeWitt*, J. A. D'Andrea, Rita Emmerson*, and Om P. Gandhi. Departments of Electrical Engineering, Bioengineering, and Psychology, University of Utah, Salt Lake City, Utah, 84112.

In previous research from this laboratory, seven male Long-Evans rats were exposed to low-level microwave radiation (2450 MHz, .5 mW/cm^2) for periods of 3 months. Though most behavioral measures and nonspecific measures of health status were not different from those of sham-radiated rats, the radiated rats were extremely slow on average to learn to avoid footshock in a shuttlebox avoidance task. Individually, four of the radiated rats failed completely to avoid footshock through 50 training trials; whereas only three radiated rats performed at levels more typical of non-radiated controls. In an attempt to study this effect further, radiation (14 rats) and sham-radiation (14 rats) conditions were repeated with additional rats and a third group, caged control rats (14 rats), was added to the design. Results of the shuttlebox tests with these three groups are presented and compared both with previous findings and with results of several other behavioral tests conducted on the same rats, including a) an open field test, b) an appetitive task with DRL (differential rate low) schedule of reinforcement, c) shock sensitivity tests, and d) several nonspecific measures of health status.

O-10 HUMAN SENSITIVITY TO TRANSIENT ELECTROCUTANEOUS STIMULATION. J. Patrick Reilly, Willard D. Larkin*. Johns Hopkins University Applied Physics Lab, Laurel, Md. 20707.

The purpose of our research is to quantify human reactions to electrocutaneous stimulation by high voltage, short duration transients. Human subjects were exposed to stimulus levels ranging from below perception to the limits of tolerance. Stimulating currents consisted of monophasic (current passing in one direction) exponential capacitive discharges, and biphasic (current alternating in direction) exponentially decaying sinusoids. Stimuli were delivered via cutaneous contact electrodes, spark discharges, and subcutaneous needles. Our data reveal perceptual sensitivity dependencies with respect to stimulus duration, body location, skin temperature, tactile masking, electrode size, stimulus polarity, method of applying the stimulus, and monophasic versus biphasic waveforms. We present a linear perceptual model for monophasic transients using electrical properties of excitable membranes. The model predicts that perception is accounted for by a constant charge criterion for transients which are short in comparison with the membrane time constant. Long duration transients depart significantly from the constant charge criterion. Strength/duration relationships derived from this model are in good agreement with our perceptual data. The perceptual data for biphasic stimulation reveal significant differences from the monophasic data. For the biphasic waveforms, our data suggest that the perceptual model must include nonlinear membrane response which occurs after the initiation of an action potential.

O-11 HUMAN PERCEPTION OF 60 Hz ELECTRIC AND MAGNETIC FIELDS. Charles Graham, Mary R. Cook,* and Harvey D. Cohen. Midwest Research Institute, Kansas City, MO 64110

During construction of a laboratory facility to evaluate the effects of human field exposure, we made informal observations of field perception on 3 women and 16 men. Surprisingly large individual differences were apparent. Perception thresholds for a uniform electric field ranged from 5 kV/m to 22 kV/m. Sensation type and locus varied. Perception reports were influenced by suggestability and by the preexisting static charge on the limb. Since the literature on human field perception is both sparse and contradictory, we are now in the process of conducting a controlled study on 10 men and 10 women. Perception of uniform 60 Hz electric fields (0 to 22 kV/m) and magnetic fields (0 to 32 A/m) will be evaluated while subjects wear standard clothing and are grounded. Testing procedures include psychophysical methods and signal detection techniques used under controlled conditions of temperature and humidity. Findings will be reported on the effects of six factors (sex differences, diurnal variation, exposure duration, threshold stability over time, locus and type of sensation) expressed as a function of the imposed field and as a function of induced body current. (Supported by Contract No. 21082-03, New York State Department of Health.)

O-12 ANTICIPATION OF SEISMIC AND VOLCANIC EVENTS BY ANIMALS AND HUMANS: A POSSIBLE BIOLOGICAL/GEOPHYSICAL COUPLING EFFECT. Christopher H. Dodge,* 217 5th Street S. E. Wash. D. C. 20003, Charlotte King,* Sacramento, Cal. 95820, Michael Browne,* Sacramento, Cal. 95820, S. Windward,* NYC, N. Y. 10014, and Stephen Porges,* Dept. of Psychology, U. of Illinois, Urbana, Ill. 61820

Since 1981, a voluntary project (Project Migraine) has been underway in an attempt to study human behavior and symtomatology as possible premonitors of seismic and volcanic events. The results of two years of research on the subject seem to indicate a good correlation between changes in human behavior and symptoms and major seismic and volcanic events. The international literature on animal behavior preceding seismic and volcanic events is reviewed. It is speculated that anomalous animal and human behavior preceding major seismic and volcanic events may be caused by fluctuations in the electromagnetic environment, fluctuations in barometric pressure, or other physical factors in the environment. At present, the electromagnetic theory seems most attractive. Suggested directions of future research into this phenomenon are suggested.

0-13 COMMON FEATURES AND SPECIFICITY OF THE BODY RESPONSE AT THE COMBINED ACTION OF IONIZING AND NON-IONIZING RADIATION. Yu.Grigoriev. Institute of Biophysics, Moscow USSR.

The results of experimental studies on the combined action of γ radiation and microwaves have been presented. Radiosensitivity in rats after preliminary exposure to microwaves (200 $\mu W/cm^2$) was estimated, imprinting reaction in chickens (40 $\mu W/cm^2$) was characterized, and the influence of γ radiation and microwaves on behavioural responses in rats/0,34 Gy and 40 $\mu W/cm^2$) was investigated. Three types of responses were obtained.

SESSION P Dosimetry IV

Cochairs: Koichi Shimizu and Maria A. Stuchly

P-1 IMPROVED CALCULATIONS OF SAR DISTRIBUTIONS IN BIOLOGICAL MODELS. Chi-Tsou Tsai*, Habib Massoudi, Carl H. Durney, and Magdy F. Iskander*. Department of Electrical Engineering, University of Utah, Salt Lake City, UT 84112

A central problem in contemporary dosimetry research is how to calculate internal SAR distributions, which is much more difficult than calculating average whole-body SARs. For example, the moment method using pulse basis functions has been found to give good values for whole-body SAR but the convergence of the solution for SAR distributions is questionable. In particular, the expansion of the unknown fields in terms of pulse basis functions cannot satisfy boundary conditions at the mathematical cell walls. We describe a new technique for calculating SAR distributions using Galerkin's method with linear basis functions and polyhedral mathematical cells. We reverse the order of integration to average over the cells first and integrate over the sources secondly. Also, the integration for averaging is carried out over an inscribed spherical volume, not the entire mathematical cell. This allows analytical instead of numerical integration and alleviation of numerical problems related to singularities. Polyhedral cells also allow smoother models. We have calculated the phase and magnitude of the internal E field at every point in a homogeneous sphere at low frequencies within ±2 percent for ϵ' up to 9 and within ±12 percent for $\epsilon' = 40$. We expect shortly to have similar results for ϵ' up to 100.

P-2 A BOUNDARY-ELEMENT FORMULATION OF FIELD PROBLEMS
B. Tuerlinckx (x,1), M. Diarickx (x,1), L. Rybowski (x,1), M. Hinsenkamp (2), F. F. Burny (x,2)
(1) Electricité générale, Faculty of Engineering, U.L.B.
(2) Chirurgie Osseuse, Erasme Hospital, U.L.B.

A realistic knowledge of the actual local electromagnetic conditions at the site of the non-union would help understand the mechanism of fracture repair by weak pulsed electromagnetic fields. This envolves the solution of Maxwell's equations in a three-dimensional, anisotropic, inhomogeneous medium.

We show how this problem can be simplified by making some weak physical assumptions and using the Boundary-Element method for alliptic partial differential equations. The latter is particularly well suited to solving the numerical difficultias one often encounters in similar conditions with the classical methods. Furthermore, the program can easily be developed stepwise, from a simplistic case with a healthy, isotropic bone and low frequencies to the more interesting situation featuring the fracture, anisotropic properties and a broad spectrum signal.

Numerical results and validity tests are given.

P-3 EXPERIMENTAL VERIFICATION OF SCALING MODEL USED TO PREDICT ENHANCED CALCIUM EFFLUX FOR VARYING RF FREQUENCIES. Claude M. Weil, William T. Joines, and Ronald J. Spiegel. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711

In studies involving the enhanced efflux of calcium ions during in-vitro irradiation of chick-brain hemispheres, controversy has arisen regarding the adequacy of the sphere models that have been used to scale the positive and negative effect amplitude windows from one RF frequency to another (50 MHz v. 147 MHz v. 450 MHz). Experiments have therefore been undertaken to measure the internal electric field strength within a chick brain surrounded by buffer solution at these three frequencies. Measurements are performed using a miniature insulated electric-field probe (2.5mm length) that protrudes through the side-wall of a TEM-mode rectangular strip line into the sample. The latter is contained in a vertically-bisected test tube that is mounted on the inside of the side wall. The experimental data confirm that predicted from the homogeneous sphere; agreement with the inhomogeneous model data was not as good. A related experiment also confirmed the predicted reduction in internal field strength due to the presence of adjacent samples located on either side of the measured sample.

P-4 USE OF LF PHANTOM MATERIAL TO STUDY THERMAL DISTRIBUTIONS IN THE NEAR FIELD. W.S. Yamanashi, J.D. Forster, A.W. Boddie* and Joseph Ford*. Departments of Radiology, M.D. Anderson Hospital and Baylor College of Medicine, Houston, TX 77030

Three types of near field applicators were compared with respect to free space electric and magnetic field distribution and thermal energy patterns in phantoms resulting from the induced current. These applicators include (1) a conventional helical coil diathermy applicator, (2) a near field synthesizer designed for regional hyperthermea (3) a whole body NMR imager, and (4) a high field, small bore NMR "mini imager". Tissue phantoms chosen to operate in the frequency range of these applicators were used to map the thermal distribution of the absorbed power. Temperature measurements were done with liquid crystal sheets of an appropriate temperature range and two temperature probes to give values at specific points. The results of these studies may be useful in (a) the selection of diathermy/ hyperthermea applicators and (b) the evaluation of potential biohazzards in NMR imaging.

P-5 THREE-DIMENSIONAL VISUALIZATION OF ENERGY DEPOSITION IN HUMAN MODEL EXPOSED TO ELECTROMAGNETIC WAVES. ITSUO YAMAURA. Radio-and Opto-electronics Division, Electrotechnical Laboratory, Sakuramura, Niiharigun, Ibaraki-ken, JAPAN

Synthetic paste is used as the visualization material, which is composed of water, polyvinyl alcohol, and non-ionic surface active agent. The surface active agent dissolved in water comes out of the solution,making the solution opaque when the temperature exceeds a critical level, which is called cloud point. The material with cloud point of 45 °C is filled in the thin glass vessel of which shape constructs scale model of a woman torso. 2,450 MHz microwave was radiated to the model with output power of 600 W from a horn antenna. In a few minute, hot spot appeared in the neck as a white spot, and in course of time white formations arised in the mamma and the thigh. Surface of the abdomen became white at last. The size of white formations elicited in the model gradually increased, and the shape of them was deformed. As heat conductivity of the material is very low, the profile of the surface of the formations gives an isoenergy deposition.

P-6 INTERACTION OF THE NEAR-ZONE FIELDS OF A SLOT ON A CONDUCTING SPHERE WITH A BIOLOGICAL SPHERE. Shi-Guo Zhu, Huey-Ru Chuang and K.M. Chen, Department of Electrical Engineering and Systems Science, Michigan State University, East Lansing, MI 48824

We consider the geometry of a biological body, simulated by a lossy dielectric sphere, located near a slot source on a conducting sphere; this geometry idealizes the situation of a man exposing to the leakage field of a microwave oven. The spherical geometries are adapted to obtain an exact solution to the problem. With an exact solution, it is possible to accurately estimate the coupling effect between the body and the source (conducting sphere). To solve the problem, two spherical coordinate systems are used to describe the conducting sphere (source) and the dielectric sphere (body). The addition theorem is used to translate the EM fields between these two coordinate systems. Multiple reflections between the conducting sphere and the dielectric sphere are determined by solving the boundary value problem iteratively. The final solution is obtained when the iterative solutions of multiple reflections come to converge. An extensive numerical computation was conducted to determine the induced field inside and the scattered field outside the body, and the body-source coupling effect. It was found that more than 50% error in the estimation of SAR in the body can be caused if the body-source coupling is neglected, a common approximation used in most of the existing studies on the subject.

Author Index

Adachi, K. 65
Adair, E. R. 48,54,105
Adams, B. W. 48,105
Adey, G. R. 26,27
Adey, W. R. 2,25,28,45,70,115
Agafonova, T. A. 14
Akel, G. M. 105
Akimenko, V. Y. 85
Akoev, I. G. 14,17
Albert, E. N. 58,1D3
Allis, J. W. 1
Almeido, S. P. 62
Alves, R. V. 32
Arber, S. L. 26,3D
Asakura, T. 65
Aslan, E. 32,83
Athey, T. W. 37,49,67,96
Babij, T. M. 33
Balcer-Kubiczek, E. K. 1
Balzano, Q. 33
Barnes, F. S. 27
Barski, M. 111
Barton, O. G. 107
Bartsch, D. A. 60,71
Bassen, H. I. 66
Bawin, S. M. 28
Beard, O. 21
Bechtold, G. 65
Becker, R. O. 5
Belonozhko, N. G. 85
Benane, S. G. 28
Benes, L. 18
Bentall, R. H. C. 21,55
Bezdolnaya, I. S. 85
Binjie, S. 72
Birenbaum, L. 18
Bisceglia, B. 13
Bishop, R. R. 90
Bishop, W.H. 44,49
Blackman, C. F. 28,73
Blasko, J. C. 22,53
Blum, F. O. 63
Blumel, G. 77
Boddie, A. W. 120
Bonanno, G. 4D
Bond, J. O. 62
Boraie, N. A. 103
Borup, D. T. 66
Bostrom, R. 34
Brandt, C. L. 25
Bristol, K. S. 36
Brown, R. F. 56
Browne, M. 117
Bruce-Wolfe, V. 45
Budinger, T. F. 36
Burdette, E. C. 62
Burencov, M. S. 46
Burny, F. 119
Burton, M. L. 25
Buschbomb, R. L. 42
Bustamante, J. 29
Butrous, G.S. 107
Byus, C. V. 2
Cain, C. A. 43,44,53.73
Calle, E. E. .....B
Camm, A.J. 107
Campbell, N. L. 25
Caorsi, S. 82
Carpenter, R. H. 42
Casseday, J. H. 46
Chang, S. 65
Chatterjee, 1. 37,64,67
Cheever, E. 63
Chen, G. 7B
Chen, K. M. 19,109,121
Chiabrera, A. 40
Chou, C. K. ...9,2D,24,5D,51,76,7B, 87,89,94,99
Christopher, J. P. 44,74
Chrobak, J. 6D
Chuang, H. 121
Cleary, S. F. 6,37
Cleveland, R. F. ... .67
Cobban, R. M. 55
Cohen, G. 58
Cohen, H. D. 81,117
Conover, D. L. 33,59
Cook, M. R. 117
Cory, W. E. 52
Cox, C. 114
Creim, J. A. 113,114
Cremer-Bartels, G. 2,88
Cruz, J.E. 33
Czerski, P. 7,57
D'Ambrosio, G. 13
D'Andrea, J. A. 79,92,115,116
D'Anna, S.A. 15
Dal Conte, G. 18
Davis, C.C. 3
DeFord, J. F. 93
DeLorge, J.O. 51,114
DeWitt, J. R. 79,92,115,116
Delalic, Z. 65
Delgado, J. M. R. 29,103
Deloff, L. 45
Di Fiore, P. P. 13
Dickinson, R. J. 19
Dierickx, M. 119

P. 122 thru P. 130 BLANK

Djachenko, V. 66
Dodge, C. H. 7,117
Dong, A. M. 9
Downs, R. C., Jr. 7
Driver, L.D. 33
Duarte, L. R. 22
Dudney, C. S. 8
Dumansky, Y. D. 8
Dunkelberger, G.R. 15
Durney, C. H. 106,119
Dutta, S. K. 29
Dyachenko, V. N. 109
Easterly, C. E. 8
Edwards, G. S. 3
Eichmeier, J. 77
Emmerson, R. Y. 79,92,115,116
Endo, H. 110
Engebretson, T. O. Jr. 22,53
Engovatov, V. V. 46
Eriksson, A. 84
Erwin, D. N. 14,41,71
Estes, S. 24
Fatmi, M.B.E. 92
Faulkner, D. N. 70
Fletcher, R. M. 2
Fomenko, B. S. 14
Ford, J. 120
Forster, J. D. 120
Forsythe, W. C. 97
Foster, K. R. 63
Fowler, I. 61
Frei, M. R. 47,75,76
Friedberg, W. 70
Friend, A. W. 50
Fujita, T. Y. 36
Furia, L. 13
Gage, M. I. 113
Galich, L. 109
Galvin, M. J. 47,68
Gandhi, O. P. ...13,37,64,66,67,92, 93,116
Garber, F. 6
Garner, R. J. 85
Garrison, R. G. 41
Gartner, S. L. 50
Gary, K. 4
Gee, W. 53
Geller, S. 23
Gengdong, Y. 75
Genzel, L. 65,83
Geyer, A. B. 36
Ghods, A. 19
Ghosh, B. 29
Giannetti, G. 40
Gilbert, S. C. 45
Gillis, G. 21
Gillis, M. F. 98
Glaser, Z. R. 7
Gokhale, A. V. 16
Goodman, E. M. 69
Gordon, C.J. 86
Gordon, R. 90
Goulding, F. S. 36
Graham, C. 81,117
Grattarola, M. 40
Greenebaum, B. 69
Grigoriev,Y. 118
Grin, A. N. 85
Griner, T. A. 93
Grissett, J. D. 59
Gu, Y. 67
Gupta, S. C. 79
Guy, A. W. 9,20,24,50,51,76,78, 86,87,89,94,99
Hagmann, M. J. 48,82
Han, Q. 18
Hand, J. W. 19,20
Hanson, J. S. 42
Hansson, H. 30,102
Harris, C. R. 14
Harrison, G. H. 1
Hart, F. X. 63
Hartsgrove, G. 35,111
Heinmets, F. 47,75,76
Helm, E. M. 70
Herrans, J. G. 34
Hill, D. A. 95,96
Hill, D. W. 13
Hilton, D. I. 64,113
Hinsenkamp, M. 119
Hirst, L.W. 15
Hjeresen, D. L. 86
Ho, H. S. 49,96
Homer, L. D. 3
Horita, A. 89
House, D. E. 28
Huai, C. 43,72,75
Hunter, J. 74
Hurt, W. D. 80,97
Indart, M. 60,71
Iskander, M. F. 106,119
Jacobson, R. 100,101
James, J. R. 20
Jauchem, J. R. 47,75,76
Johnson, C. S. 112
Johnson, K. 58
Johnson, M. J. 81
Johnson, P.H. 59

Johnson, R. 8. 76,87
Johnson, R. H. 20
Johnston, R. 43
Joines, W. T. 28,46,111,120
Jordan, C. A. 62
Justesen, D. R. 39,40,41,45,69
Kalyada, T. V. 10
Kanai, H. 64,93
Kaune, W. T. 42,64,97,98
Kelman, 8. J. 88
Kiel, J. L. 41,77
Kim, Y. A. 14
King, C. 117
Kinn, J. 8. 106
Kobayashi, T. 110
Kobler, J. 8. 46
Kornhouser, G. 58
Koschnitzke, C. 56
Kraszewski, A. 35
Krause, K. 2,88
Kremer, F. 54,56,65,83
Kriho, V. 30
Krivova, T. I. 10
Krupp, J. H. 42
Kryscio, R. 24,61
Kuchle, H. J. 2,88
Kues, H. A. 15
Kunz, L. L. 76,87
Lai, H. 89
Lakhtakia, A. 106
Larkin, W. D. 116
Lary, J. M. 33,59
Laties, V. G. 114
Leach, W. M. 57
Lebda, N. A. 91
Lebowitz, R. M. 112
Lecuyer, D. W. 80
Ledda, J. L. 19
Lee, S. W. 53
Leonard, J. 8. 63
Levin, R. L. 82
Levinson, D. M. 39,40,69
Lewter, O. H. 72
Liboff, A. R. 3
Liburdy, J. A. 107
Liburdy, R. P. 4
Liddle, C. G. 72
Lin, J. C. 26,30,31
Lin-Liu, S. 70
Liu, L. 6,37
Livingston, G. 37
Long, M. D. 86
Los, I. P. 12
Lotz, W. G. 51,59
Lovely, R. H. 113,114
Lozano, L. G. 80
Luk, K. H. 20,24,78
Lundak, R. L. 2
Magin, R. 53
Mahlum, D. D. 88
Mahoney, M.D. 28
Male, J. C. 107
Manikowska-Czerska, E. 57
Marron, M. T. 69
Marshall, S. V. 56,108
Martin, J. T. 17
Massoudi, H. 119
Matsumoto, G. 110
Mayaud, C. 4,61
McAfee, R. D. 90
McCulloch, D. 1
McDougall, J. A. 50,94
McEuen, M. C. 25
McKnight, C. 21
McLeod, 8. R. 24,108
McManus, M. W. 112
McNaughton, B. L. 26
McRee, D. I. 47,68
Mealing, G. A. R. 78,100
Meldrum, S.J. 107
Meltz, M. L. 14,71
Merritt, J. H. 77
Michaelson, S. M. 91
Mild, K. H. 34,84
Millar, D. 8. 44,74
Miller, M. C. 64
Min, W. 43
Misra, D. 109
Mitchell, C. L. 68
Mittra, R. 52,53
Modak, A. T. 101
Monahan, J. 58,68
Montaigne, K. M. 16
Monteagudo, J. L. 103
Morgavi, G. 15
Motzkin, S. M. 18
Murray, W. E. 33
Musil, J. 10
Nakatsuji, N. 58
Neilly, J. P. 30,31
Neuhaus, 8. 51
Nguyen, Q. A. 91
Nickitina, V. N. 10
Nilsson, G. 34
Norton, L. 23
O'Conner, M. E. 60,71
Olsen, R. G. 51,90,93
Pafkova, H. 60

Parker, R. 108
Parshad, R. 29
Penn, A. 4
Persson, L. 30
Petrowicz, O. 77
Pettit, S. 91
Phillips, R. D. 42,113,114
Pickard, W. F. 16
Pilla, A. A. 4,23
Pivirotto, P. J. 48
Poglitsch, A. 56,65,83
Polonis, J. J. 52
Poo, M. M. 70
Popovic, P. 21,38,104
Porges, S. 117
Powell, M. R. 17
Proksa, J. C. 60,71
Putnam, J. P. 72
Quick, P. 56
Quinlan, W. J. 91
Rabinowitz, J. R. 5
RamaRao, G. V. 44,73
Ramirez, E. 103
Ramon, C. 17
Rauscher, W. 54
Raveane, A. 40
Rawson, R. O. 54
Reeves, D. L. 69
Reilly, J. P. 116
Rhodes, L. C. 23
Riddle, M. M. 85
Ridella, S. 15
Riffle, D. W. 39,40,45,69
Rogers, R. R. 85
Rogers, W. R. 52
Rommereim, D. N. 42
Rosenthal, S. W. 18
Rowe, D. G. 85
Rozell, B. 30
Rudnev, M. I. 11,109
Rybowski, L. 119
Salimov, R. M. 46
Santo, L. 54,56
Scaglione, A. 13
Scarfi, M. R. 13
Schaefer, D. J. 34,35
Schaubert, D. H. 96
Schumacher, D. R. 22,53
Schwartz, J. 78,100
Scronce, B. L. 112
Seals, J. 35
Sekimizu, H. 110
Serdyuk, A. M. 11
Shandala, M. G. 12
Sharpe, S. M. 34,35
Shepeleva, M. V. 10
Sheppard, A. R. 25,28
Sherif, M. F. 58,103
Shifrine, M. 41
Shimizu, K. 110
Shnyrov, V. L. 17
Sikov, M. R. 42
Sinha, B. L. 1
Sisken, B. F. 24,61
Slaby, F. 58
Smialowicz, R. J. 85
Smith, R. F. 41
Snyder, L. 70
Soldatenkov, V. N. 12
Sorensen, C. 20,94
Spiegel, R. J. 92,104,111,120
Spiers, D. E. 48,105
Sreenivasan, A. 79
Stancampiano, C. 114
Stavinoha, W. B. 101
Stern, S. 114
Stuchly, M. A. 35,80
Stuchly, S. S. 35,111
Studwell, M. L. 35,62
Subramoniam, A. 29
Sukenik, H. J. 115
Sultan, M. F. 52
Sutton, C. H. 21,104
Svennung, N. 30
Svensgaard, D. J. 74
Swicord, M.L. 3
Symons, S. 111
Takashima, S. 65
Tam, B. 111
Tansman, L. S. 23
Tenforde, T. S. 36
Thaxton, J. P. 47
Tilson, H. A. 68
Toler, J. 38
Tompkins, W. A. F. 43,44,73
Trzaska, H. 36
Tsai, C. 119
Tuerlinckx, B. 119
Varetski, V. 66
Varetsky, V. V. 109
Vasquez, B. J. 45
Vishnyak, S. M. 85
Viviani, R. 40
Wachtel, H. 26,27,100,101
Walker, K. 71
Walsh, P. J. 8
Ward, T. R. 74,104
Weigel, R. J. 98

Weil, C. M. 120
Weisman, D. 33
Wickersheim, K. A. 32
Wike, E. L. 69
Wilson, B. S. 46,73
Windward, S. 117
Witt, K. 37
Wong, L. S. 77
Yamanashi, W. S. 120
Yamaura, I. 121
Yan, L. 43,72
Yeandle, S.S. 74
Yee, K. C. 99
Yifu, W. 72
Zartman, G. 100
Zecca, L. 18
Zhadan, G. G. 17
Zhu, S. 121

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8 84

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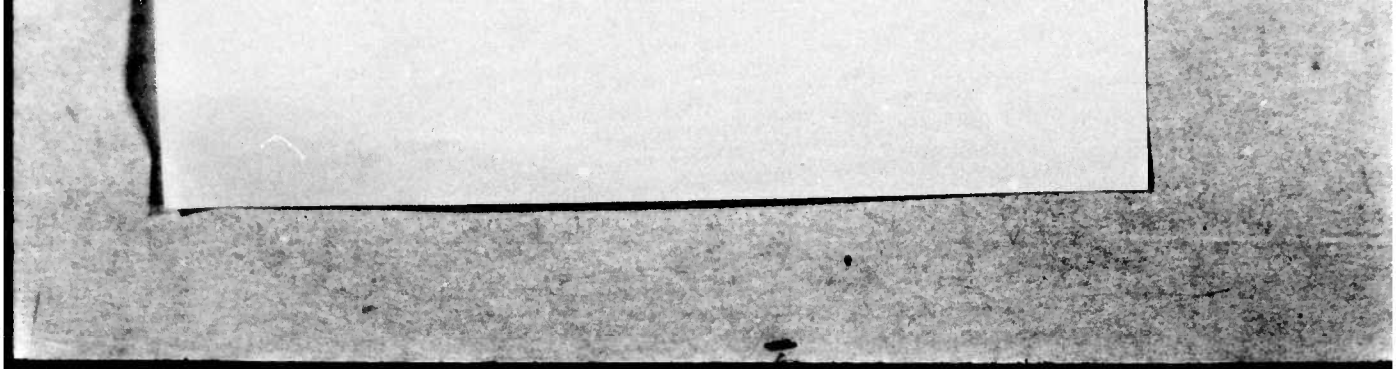

Browne, M. .....
Bruce-Wolfe, V. 45
Dierickx, M. 119

P. 122 thru p. 130 BLANK